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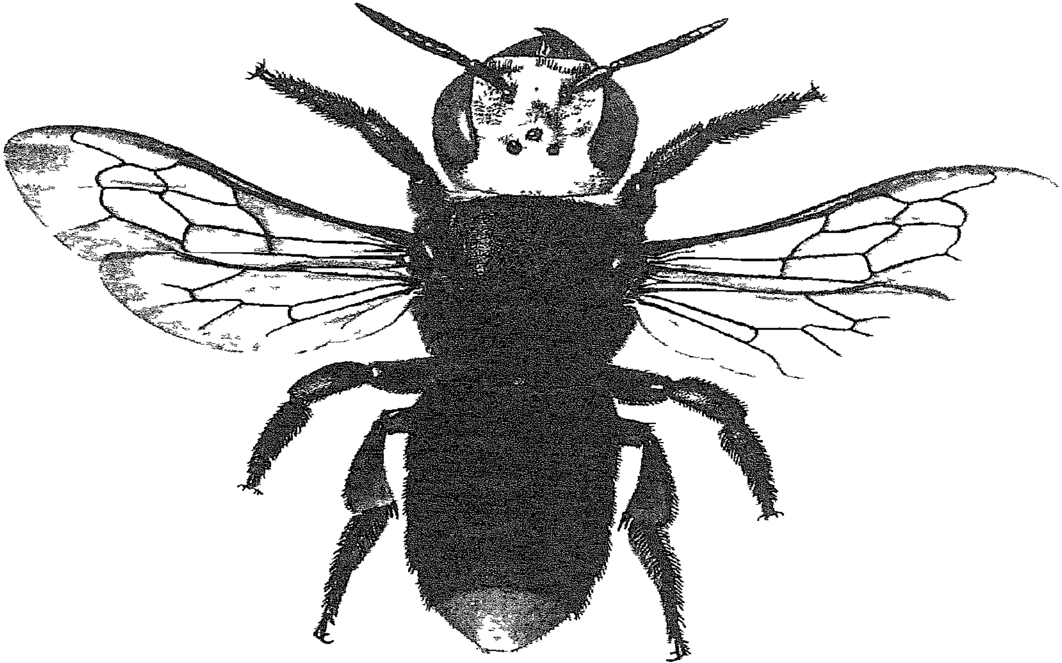
THE WORLD OF BEES



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THE WORLD OF BEES

GILBERT NIXON

Illustrations by Arthur Smith

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HUTCHINSON
Stratford Place
London

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Hutchinson & Co. (Publishers) Ltd
London New York Toronto
Melbourne Sydney Cape Town

First published 1954

638.12
N736W

Printed in Great Britain
by The Anchor Press, Ltd.,
Tiptree, Essex

ACKNOWLEDGEMENTS

In writing this book, I have been helped by contributions that other entomologists, past and present, have made to our knowledge of bees. In borrowing from their work, I am deeply conscious of my debt to them.

I have had other assistance, too—of a practical kind. To Maurice Burton in particular I offer my sincere thanks for persuading me to write a popular book about bees and for helping me afterwards by reading a part of the typescript and making many valuable suggestions. To Everard Britton I also express my indebtedness. He read several chapters of the typescript and helped me to explain more clearly certain aspects of the book that might otherwise have remained obscure. I am also grateful to members of the staff of the Bee Research Department, Rothamsted Experimental Station, for drawing my attention to statements that required qualification. Lastly, my special thanks are due to my wife for reading the proofs and for never failing, at any time, to give me the encouragement I often needed.

Arthur Smith, who did the illustrations, knows how highly I esteem his beautiful work. He earns my thanks for giving me the benefit of his artistic ability.

GILBERT NIXON

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Chapter One

WHAT IS A BEE?

MY INTEREST in bees was alive when I was very young. First adventures with them are for the most part forgotten, but a few impressions have remained sharp and clear in my memory. There was, for instance, the first big bumble-bee that ever became my prisoner. I had it beneath an upturned wineglass that had been thrown out because of a broken stem. I can remember, too, the fragrant scent of the brown bees that were fond of sunning themselves on the trunk of an old cherry tree towards the end of a spring afternoon. I used to catch them with a jam jar from which I soon learnt to pick them out with my fingers. Being young and holding a small live object in my fingers, I soon discovered that this particular bee had a pleasant smell.

Then there was the red bee, a most desirable little creature that came to the flowers of the gooseberry. Although its movements seemed leisurely, it had a knack of slipping off quickly out of reach of my jam jar. Even more of a prize was the black bee that had the habit of hovering motionless over the flowers of the polyanthus before it would settle, with the utmost grace and lightness, to take a sip of nectar.

Years later I learnt that my red bee had once been christened with the Latin name *Andrena armata*, and that my black bee was known as *Anthophora pilipes*. Another thing I found out about them was that they were the females of their kind, and that I had always known but not recognized their mates, who were plain brown in colour and decidedly dingy by comparison.

I was also well acquainted with the honey-bee, though for some reason of obscure origin I did not care for it as much as I liked its wild relatives. It was the intruder that had no place in my private and very exclusive world of bees. Had it not come from a hive where it was tended by human and unhallowed hands? This much I had been told, though the unhallowed part I added myself. But with the wild bees it was very different; there was hardly a person about me who even so much as suspected their presence. So that I felt that I alone, with the naïve ignorance of the very young, was privileged to claim them for my own and probe their secrets.

Since those early days, bees have charmed and delighted me. I have even dropped my snobbish disdain for the honey-bee and become one of her most slavish admirers.

It may sound a little odd perhaps, but for many years I knew more about the habits of certain bees than how many different kinds of bees there were or how it was possible to distinguish one sort from another, apart from obvious differences in size and colour. It was a long time before I could bring myself to abandon my first love, the butterflies and moths, and make a collection of bees instead. The changeover was made easier through the gift of a hand lens that a sympathetic father fished out of a drawer of odds and ends.

The lens had a low magnification but it nevertheless gave my bees a new appearance, a quality of form and colour and texture that hitherto they had not possessed. It was exciting to see whether a small black bee, a bare quarter of an inch in length, had a round face or an oval face, to see whether the hairs that clothed its body were long or short and to decide whether or not the middle part of its body—the thorax—had a greenish tint.

This was my first introduction to insect classification and it fascinated me. An eminent entomologist, Edward Saunders, long since dead, had gathered together in a book called *Hymenoptera Aculeata* all that was known about the bees of the British Isles and had pointed out with great technical skill how the different kinds or species could be distinguished one from another. This book I managed to buy; I valued it like a Bible.

It is, I know, quite usual to make fun of those people who get pleasure from looking for the small details that make one species of insect different in appearance from another. 'Museum men' they are called, concerned more with the anatomy of a dead insect than with the mystery that makes it, when alive, an object of occasional attention.

For me, however, the interest in bees was not suddenly shifted to their dried and pinned bodies. What did happen, though, is that I began to get more pleasure from observing live bees when I had some sort of idea how they looked when they were dead. The brown solitary bee that settled on the trunk of the cherry tree became more than just a brown bee with a fondness for basking in the sunshine. It became a particular kind of bee with its own special characteristics and a name by which it could always be known.

When I first began to make a collection of bees, I was already aware of certain rather obvious facts concerning the behaviour of some of them. If you love insects, as I did as a child, you just cannot help noticing the sort of thing they do openly, and when you see the same piece of acting repeated one summer after another, it acquires almost the invariability of the seasonal changes themselves. I knew that the red *Osmia* bees visited damp spots in the garden in order to scrape up a small pellet of clay which they bore off. Each year I could count on their coming almost to the same corner of the garden to get their loads of clay, though what they wanted the clay for I was never able to find out. It was years later, when I had learnt the names of the bees, that I was able to sort out the little bits of knowledge I had absorbed through long and close familiarity with them and attach these facts of behaviour to the actual species of bee they concerned.

There is, I am afraid, no short cut for you either. If you wish to know something about bees, you must allow me to give you at least an outline of what they look like. There is no startling distinctiveness about a bee. Quite a lot of two-winged flies—Diptera to give them their scientific name—are very much like bees and no one need feel ashamed if occasionally he mixes the two. This was brought home to me many years ago in a most convincing manner. A woman visitor came to the Natural History Museum in South Kensington and said that some horses of hers were being worried by large brown flies that flew into the stables and made a set at the horses. She had, she said, caught one of these tiresome flies and brought it with her for me to look at. It was a bee—the brown male that belonged to the black bee of my childhood days. I pointed out to the lady with the utmost diffidence that this could not have been the insect of which she complained, for it was a harmless bee with no liking at all for the atmosphere of a stable. She gave me a withering look, put the bee back in her handbag and said, with a cutting emphasis on each word, "Young man, I don't think you know what you are talking about."

The explanation was in reality simple. The insects that bothered my indignant visitor's horses were almost certainly bot-flies, large hairy insects that on the wing look very much like bees and which pass the grub stage of their life history in the stomach of a horse. The lady had every reason to be worried about her tormented horses; but unfortunately she had been content to go to her flower-bed and catch up the first bee that looked like the bot-flies in the stable.

The only moral to this story is that your eyes can let you down badly. Describe to a lepidopterist friend the next pretty moth you see and ask him to identify it. The chances are that your description will be so vague and inaccurate that if he is rash enough to try and name your moth from it he will be wide of the mark.

There are more insects in the world than any other kind of animals. In order that we may not be bewildered and overwhelmed by the diversity of their form, they have been arranged, for convenience, into several very large groups called orders. Butterflies and moths, for instance, form the order Lepidoptera; beetles are known as the Coleoptera; and the various kinds of grasshoppers, together with stick insects and cockroaches, all belong to the order Orthoptera. There are several more of these orders, but we are concerned only with the one known as Hymenoptera.

Hymenoptera is the name given to a huge assemblage of insects that have certain features in common. Bees form only one small part within the larger whole. It would not be especially interesting to go into all the fine technical points, the various details of structure with their heavy Latin and Greek names, that make all these hymenopterous insects different from other kinds of insects. It is better to stick to a few essentials and travel light.

The word 'Hymenoptera' has a useful and descriptive meaning; it is derived from two Greek words: 'hymen', a membrane, and 'pteron', a wing. Membranous-winged; such are the bees and their relatives. But having thin, transparent wings is not in itself a sure enough guide to the identity of a member of the Hymenoptera, because the Diptera, or two-winged flies, also have membranous wings. What is important is that a bee has four wings, a pair on each side, with the front one of each pair always larger than the hind one. In flight, the two wings are locked together and function as one. The locking device is simple; the hind margin of the front wing has a short, turned-over edge which engages with a row of little hooks along the front edge of the hind wing.

The bees have some relatives within the great family that are closer to them than others. These are the wasps and the ants. They are first cousins to the bees, whereas such other Hymenoptera as ichneumon-flies, gall-wasps and saw-flies are so distantly related that their connection with the bees, wasps and ants can no longer be satisfactorily traced.

It is worth while pointing out here, I think, that the term 'fly' is very loosely used in popular language. Strictly speaking, it should be applied only to the Diptera, the order to which belong such familiar two-winged insects as the house-fly, the mosquito and the daddy-long-legs. *Ichneumon-flies and saw-flies are, of course, not flies at all,* but their popular names bear the authority of long usage.

The bees, the wasps and the ants form a little clan of their own. Though they fall into three separate groups, distinct from one another, they nevertheless all have one special feature in common: they all have a sting, or at least the rudiments of one. It has therefore been found convenient to keep them apart from all their relatives in the Hymenoptera and to give them some sort of title of their own. They are known as the Hymenoptera Aculeata. The name 'Aculeata' is apt, since it is derived from the Latin word *aculeus*, meaning a sting or sharp instrument. *Hymenoptera aculeata* was the name of the book, you will remember, that first showed me how I could name the different species of bees that I captured as a boy.

Living organisms do not allow themselves to be nicely tidied up and pigeon-holed. They make fun of bold generalizations and produce, as though from a magician's hat, the awkward exceptions for which a qualifying codicil has to be added. I have just said that the ants, bees and wasps possess at least the rudiments of a sting. This definition is not broad enough, for if we look at this section of the Hymenoptera as a whole we find some ants that have no sting at all and a whole range of bees—the Stingless bees of the tropics—in which it is little more than a mere vestige.

It is a combination of features that gives an ant its particular stamp and allows even those that have no sting the right to a place among the rest of the aculeate Hymenoptera. The ants that do not sting, such as the large wood ants of the British Isles, have an excellent substitute concealed in their tail; this is a pouch into which certain poison glands pour their formic acid. When irritated, the ants direct the tail of the body upwards and squirt a fine spray of acid into the air. You can see this happen if you disturb one of those large anthills, composed of pine needles and bits of dry twigs that are common among the pine trees on the Surrey heaths. With a few possible exceptions, the Stingless bees have no weapon of any kind hidden in their tail. For all that, they are not without effective means of self-defence, as we shall see later.

Only females have stings; its use is essentially a feminine prerogative. It is a female organ that in the Hymenoptera outside the Aculeata functions as an ovipositor or egg-laying tube. The male, having no sting, is a helpless creature without cares or responsibilities. Nevertheless there is a use for him and he is suitably endowed with all the skills and tricks of behaviour that help him to fulfil his single function in life, which is to seek out and fertilize his mate. He throws himself wholeheartedly into his task in spite of a poor chance of reward, for it seems that there are always more male bees born into a competitive world than females for them to pursue.

The ants that we all know so well are workers and have no wings. We do not confuse them with either bees or wasps. Where the confusion lies is between the bees and wasps, the two remaining groups of the Aculeata.

The social wasp that enters the house in late summer in search of food for the hungry community of which it is a single active unit is a very different-looking insect from a honey-bee or a bumble-bee. Patterned in black and yellow, it gives the impression of being bare, hard and streamlined. The bees have a very different aspect. Here, because of the thick, dense clothing of hair, all is softness and blurred outlines. Even the yellow stripes of the bumble-bee have none of the sharpness of the yellow markings of the wasp.

If the picture were always as simple as this, even the novice would find it as easy to distinguish bees from wasps as to count the fingers on his hand. Unfortunately, these clear-cut distinctions are not maintained.

There are many thousands of different kinds of wasps and almost as many kinds of bees, and sometimes the line that separates them becomes extremely fine. It is not so much that wasps sometimes resemble bees; it is the bees rather that have a tantalizing way of turning up with the baldness and sharp colour patterns of wasps. There is no better example of this sort of disguise than that furnished by the bees known as *Nomada*. Generally they are black and yellow, with perhaps a touch of red here and there. And as they have also a slender, graceful form and are far from being hairy, they could easily pass for wasps.

If we want to find a criterion for distinguishing wasps from bees, we must reject both form and colour, however useful they may be for separating by eye most bees from most wasps. The only difference that could be put down on paper without much qualification has to be seen with a microscope or high-powered lens. The hairs of the wasp —it is not so bare as it looks—are smooth, whereas those of the bee are beautifully barbed or branched.

As with all insects, the body of a bee is made up of three parts: the head, the thorax and the abdomen. On each side of the head is a large eye composed of numerous facets. The bee's vision is quite unlike ours. Each of the minute facets that cover the convex surface of its eye is sensitive to rays of light, and as there are great numbers of facets, the impression received by the brain is a kind of mosaic light picture.

On the top of the head, embedded like minute shining beads, are three eyes called ocelli, each with a single facet. They are arranged in a triangle and are called simple to distinguish them from the much larger compound eyes. The bee uses its ocelli to distinguish between light and darkness.

Attached to the front of the head are the feelers or antennae; they are important sense organs, and one of their chief uses is to help the bee recognize different odours. On the lower part of the head the bee carries a pair of jaws or mandibles. They are especially important to the female; she uses them for biting, scraping, chiselling, as well as for moulding building materials into the desired shape. Between the mandibles lies the tongue, a tube-like organ through which the bee sucks up nectar and other fluids.

The middle part of the body, or thorax, bears the six legs and the two pairs of wings. Because it supports these organs of locomotion and flight, the thorax contains more muscle tissue than any other part of the body. This is perhaps why a wasp, should it capture a bee, will cut off its head and abdomen and carry back to the nest only the meaty thorax.

Behind the thorax and attached to it by a waist lies the abdomen. The waist seems almost too narrow to hold so heavy a part of the insect. But there is an advantage in this narrow stalk that seems so frail and is yet so securely attached to the thorax by its powerful muscles; it allows the abdomen to be moved freely in almost any direction while the thorax itself can remain rigid. The abdomen is made up of several segments or broad rings that fit together like the parts of a telescope. When the bee fills its crop or honey-sac, which is situated in the front part of the abdomen nearest the thorax, the abdomen grows longer. As the food is used up, the segments begin to telescope and the whole abdomen becomes shorter and smaller. Within the abdomen lie the organs of digestion, excretion and reproduction; and concealed within its tip, if it is a female, is the sting.

A bee does not breathe by means of lungs. Instead, its entire body is traversed by a fine network of branching tubes. These are called tracheae and through them air travels to every part of the insect's body, bringing the oxygen necessary to keep it alive. The breathing tubes are thickest where they open to the air at the surface of the bee's horny skeleton. The actual openings are called spiracles, and a bee has twenty of them, ten on each side of the body.

The spiracles of the honey-bee are particularly interesting because of their connection with the terrible Isle of Wight diseases that threatened to wipe out the entire population of honey-bees in Great Britain at the beginning of this century. At the front end of the thorax the spiracle is large enough to allow a mite, a creature of microscopic size with eight legs and distantly related to the spiders, to enter and make its abode within the hollow breathing tube. Here it lives, sucking the blood of the bee through the thin walls of the trachea. When the mites breed and multiply in the spiracles they cause great discomfort to the bee, often disabling it so that its wings no longer function properly and finally causing its death. The mite is now called *Acarapis woodi*, though at the time the Isle of Wight disease was raging no one knew of its existence in the breathing system of the bee. There are now various ways of fumigating a colony of honey-bees so that the mites are killed but the bees left unharmed.

How can male and female bees be told apart? The female, of course, has a sting. It is easy to be facetious here, but no one picks up a live bee to find out whether it has a sting in its tail or not. When bees are observed alive it is impossible to point to any one feature that will separate the sexes. If you are an expert you may be able to make use of slight differences in behaviour to pick out the males from the females. But to do this you must indeed have served your apprenticeship and acquired a deep familiarity with the ways of bees. If the bee is dead and a lens is handy, the question of its sex can be easily decided, though a steady hand and good eyesight are necessary. All you have to do is to count the number of segments in the antenna. The male has thirteen of these but the female only twelve.

Generally speaking, the female bee is the more showy, not only in her appearance but also in her behaviour. She has a far wider range of aptitudes than the male and her colours and patterns are richer and more vivid. Her mate, by comparison, is drab. The warmer tints of the female are sobered down, for him, to a colder and more uniform hue. He is so often merely brown while she shows a rich contrast of colours. In build, also, the male is less favoured than the female. He tends to be smaller and altogether less robust in appearance. There are, of course, the inevitable exceptions; in one British bee, *Anthidium manicatum*, which has no common name, the male is a huge, rather clumsy creature, while the female is barely two-thirds his size.

This difference in colour and form is one of the most interesting features of bees, though it is by no means confined to them but is a common phenomenon among insects. It is called sexual dimorphism.

Often the difference between the two sexes of a bee is simply one of degree. By this I mean that the male is more slender and his colour much less vivid in comparison with the female. Sometimes, however, the dimorphism is so sharp that it is quite impossible to associate the sexes unless they have been bred together from the same nest, or some other fact of their biology is known. A few examples will make this clearer. In the genus *Anthophora* the males of some species are brown and their females completely black. The sexes of the tropical carpenter bees, *Xylocopa*, are also frequently differently coloured; the males being often greenish yellow while the stouter females are black with perhaps a couple of white or bright yellow bands. Among the bumble-bees the contrast in colour is often so very marked that if the males and females of half a dozen British species were placed, unsorted, in front of you, you would find it extremely difficult to pair them together correctly.

Sexual dimorphism does not express itself only in colour. Sometimes the structure of one sex or the other will be modified to adapt it more smoothly to the kind of life it leads. For instance, we find in the males of some bees grotesque anatomical developments that are in some way associated with the sexual behaviour of the insect. The males of some species of *Andrena* have very large jaws that can be opened out like a pair of calipers; they are used for seizing the female tightly around the neck at the time of pairing. Others, such as *Megachile*, the leaf-cutting bees, sometimes have large flattened expansions on the front feet that help them to hold their females more securely.

Once the eye has become accustomed to the kind of differences that separate the sexes, it is not difficult, with a little practice, to pick out the males when they are at rest. There is no place where you can be more sure of finding male bees than in a bed of lavender towards the end of July. It is the bumble-bees especially that like to congregate here, for they seem to find the lavender quite irresistible. They pass from one fragrant flower spike to another, greedily sipping the nectar and refreshing themselves, presumably, for the more serious business of finding a mate.

I very soon learnt to spot these male bumble-bees and used my skill to impress those who knew nothing about insects. People would look at me in astonishment when I picked up a bee and popped it into my mouth. I was regarded as a sort of bee-charmer. But the prestige was cheaply earned, for I had acquired no mysterious power over the bees; nor were steady nerves and iron self-control a part of the performance. Having carefully studied the bumble-bees in my collection, I knew how the males differed from the females and simply put my knowledge to practical use. Lest anyone should be tempted to pick bees off the lavender and put them into his mouth, let me say at once that the worker bumble-bees, females and armed with a sting, are usually foraging among the flowers with the males. The workers of some species, such as *Bombus lucorum*, are decidedly unlike the males, but in another species, *Bombus terrestris*, they resemble each other so closely in life that you need sharp eyes to notice the subtle differences between them.

The story of the bot-flies that I told earlier is proo enough that bees often look like flies. In fact, it is only the two-winged flies, or Diptera, that are likely to be mistaken for bees, though they are, of course, entirely different in having two wings instead of four and mouth parts that are adapted for piercing and sucking, but not biting. If, in saying this, I remind you of mosquitoes, which bite and which are certainly two-winged flies, I can meet your objection by adding that it is just a convention to refer to mosquitoes and certain other flies with a fondness for blood as biting insects. These flies pierce the skin with a sharp proboscis or beak, and are quite incapable of inflicting the kind of bite that an ant, for example, can give with its pair of jaws. Apart from these fundamental differences, bees and flies often have a superficial resemblance that might deceive anyone who was not an entomologist.

One of the commonest flies in Great Britain is known as *Eristalis tenax*. It is large and brown and very like the familiar honey-bee. In the autumn both the fly and the bee are frequent visitors to the michaelmas daisies and might easily be confused. The fly, however, usually sits almost motionless on a flower as it feeds on the pollen, while the bee hurries around the corolla as though every moment of its active life were vitally precious.

Some people have suggested that *Eristalis tenax* is a mimic of the honey-bee, and that it enjoys a certain immunity from attack by resembling it. Personally, I have never found this particular example of one kind of insect looking like another of much use to the theory of mimicry. There are, however, others in which the resemblance between fly and bee is pushed far enough to have some special meaning. The fly becomes so perfect a mimic of the bee in colour, pattern and form that in life the two are almost indistinguishable. It is suggested that in the course of evolution the fly has gained certain advantages by coming to look like a bee. There is a large carpenter bee in West Africa that is black with tufts of white hair along the sides of the abdomen. A large robber fly, one of the *Asilidae*, is often found in company with the bee. The two insects are strikingly alike, even down to the little tufts of white hair.

Chapter Two

ONE KIND OF BEE, OR MANY?

WHEREVER there are flowers, especially the daisy-like blossoms of the plant family *Compositae*, they are sure to be visited by some kind of bee or other. The bees come for nectar and pollen because they are wholly dependent upon these plant products for themselves and their offspring. It is to the flowers, then, that we must go if we wish to make a collection of bees; and if we could search throughout the summer every kind of flower that grows in a district we should catch a surprisingly large number of different species. All these are popularly dubbed 'wild bees' to distinguish them from the hive- or honey-bee.

No one has yet any idea how many different species of bees there are in the world. Every year new ones are discovered and each is given a scientific name. Up to the present, thanks to the zeal of collectors who have hunted in every part of the world, and to the enthusiasm of museum workers who have studied and classified their catches, at least ten thousand different species of bees are known to science.

It is hardly possible to convey a clear idea of the wide range of size, shape and colour to be found in this vast assemblage of insects that are all of one kind. It is hard, indeed, to realize that there could be so many different bees. Yet they all conform to a certain standard of classification, having in common the essential features that make them all bees. So that if we were to examine the hairs with which their bodies are clothed we should find that they were always, in all the ten thousand different species, either barbed or branched or finely feathery.

Everyone knows the big, homely bumble-bees in their black coat with its yellow stripes. But what about those small bees that love to bury themselves in the dandelions in spring? In size between a quarter and half an inch, black in colour and extremely slender compared with the stout bumble-bees, they seem to belie their relationship with their larger cousins. Yet put them—the little bee and the large bee—side by side beneath a microscope, and you find that what really make them different has nothing to do with size but is found in the shape of the tongue, the position of the veins on their wings and the arrangement of hairs on the hind leg.

If we were to collect a dozen of these little bees—their name is *Halictus*—and tried to sort them out, we might find that they could be grouped into three or four different kinds. Looked at full face, under the microscope or with a strong hand-lens, one would have a round head, another a long, narrow head, and a third a head that was neither round nor narrow but something midway between the two. The fourth might be quite different from the other three in having a thorax metallic green instead of black. If bees were as big as birds, the differences between them would be of the same order as those between, say, a crow and a rook, or a song-thrush and a missel-thrush. And this is saying a lot, for these pairs of birds are so much alike that it takes a good ornithologist to tell them apart. Imagine a rook and a crow reduced to the size of bees and you get some idea of how difficult it is to distinguish one species of bee from another.

Most bees are very hairy insects, and the pelt, especially in the female, is often warmly coloured. For æsthetic appeal it would be hard to beat the female of *Andrena armata.* Here is a bee that has to be seen when the warmth of the spring sunshine has just lured her forth from her burrow and hard work has not yet spoiled her beauty. Above, her thick coat has the appearance of red plush; beneath, she is nothing but unrelieved blackness. But the contrast and the background of a green leaf and the sunshine of which she is a charming symbol all contrive to make the sight of this little *Andrena* a pleasant experience.

As a rule it is the colour and pattern of its hairy coat that gives a bee its distinctive quality. Just occasionally, as in South America, the home of many brilliantly-coloured insects, bees are found that are almost hairless. But they make up for this absence of a hairy coat by being lavishly adorned in another way. Such are the bees of the genus *Euglossa*, notable for their long tongue and a flashing cuirass of brilliant metallic green which makes them sparkle like jewels in the tropical sunshine.

Naturally, we know far less about the behaviour of bees than what they look like. Knowledge of the first kind always lags far behind the second. In other words, you have first got to catch your bee and learn to recognize it before you can begin to study its habits. Although I have tried to indicate that bees are often attractive enough to please the eye, it is their habits rather than their appearance that put them amongst the most interesting of all insects.

This brings me to the point where we may cease to look at bees as a whole and divide them, for the sake of studying them a little more closely, into two groups. According to how they look after their young, they may be considered to have social or solitary habits.

Most of the bees of the world are of the solitary kind. This means that a single female takes over the entire responsibility of making a nest for her family and collecting the food they will need for their development. All this she does entirely on her own.

There are a great many of these solitary bees in Great Britain. It is they who throw up those mysterious little mounds of earth on paths and lawns and cause anxious flutterings among enthusiastic gardeners. The sudden appearance of these earthworks is regarded as an evil portent of worse things to come. Actually it would be hard to imagine any insect doing less harm in a garden than these industrious bees, whose digging is soon finished and who have burrowed into the hard ground simply to make a nest for their small families.

The social bees have evolved a different way of life. They live in communities in which the greater part of the progeny of a single female, called the queen, is in a sense sacrificed to the common good. These children that are set apart are all females, but their maternal instincts are not allowed complete fulfilment. On the other hand, their capacity for work is enormously increased. They are the worker honey-bees and the worker bumble-bees, and they labour unceasingly for the prosperity of the community to which they belong. These curious sterile individuals are never disturbed by any impulse that does not promote the general welfare; they have no will of their own, nor are they ever wayward or capricious. There is no room in the matriarchal society of the social bees for behaviour that is individualistic or unconventional; there is merely a routine of labour to be gone through, and the workers apply themselves to it with a commendable thoroughness. But if these virgins seem to live as slaves, it is, indeed, only in appearance. For to be a slave one must at least be aware of an alternative way of life. But the workers of the social bees, and of the ants and wasps as well, were set upon the course of their

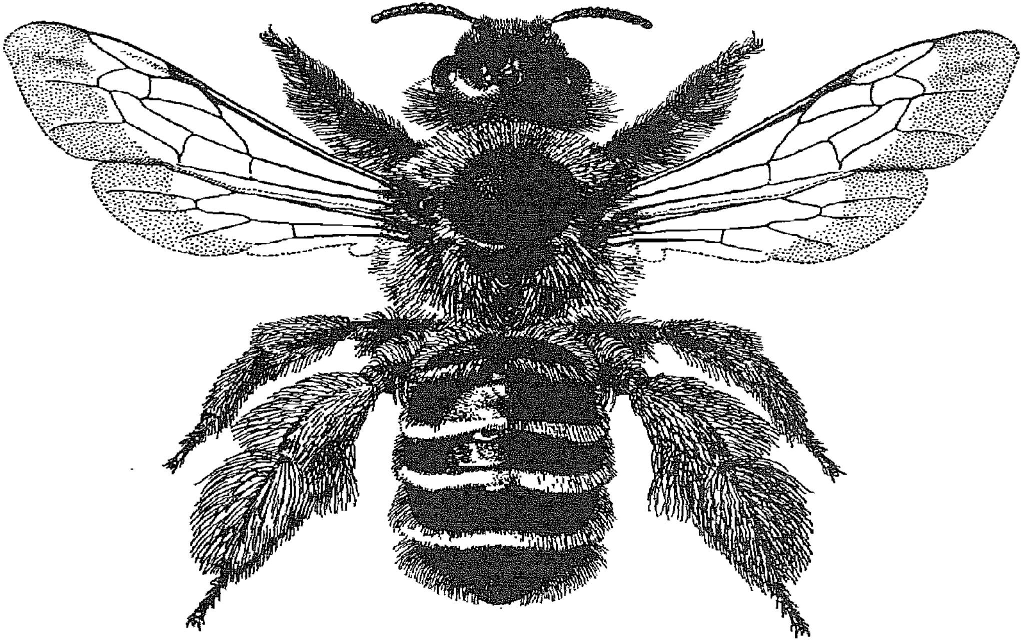

Fig. 1
A rare solitary bee that nests in the sand, mostly in coastal places in Southern England : *Dasypoda hirtipes*, female

behaviour a very long time ago and cannot possibly turn away from it.

The activities of the workers are directed to a particular end; they support an act of reproduction in which females like the queen mother and males with the capacity to fertilize them are produced within the colony. The society of the honey-bee, with its tens of thousands of sterile females dedicated to the production of some half a dozen queens in a single season, may seem a clumsy and wasteful instrument for race perpetuation compared with the single-handed labours of the solitary bee.

How the social habits of bees arose is a matter for speculation. Unfortunately, fossil evidence has little help to offer. The rocks tell us much about the evolution of form but are silent about the equally complex changes in behaviour. I make this statement with reservation, of course, since something of the habits of an animal can be deduced from its bodily structure. The teeth of a fossil animal will reveal whether it was a flesh-eater or a vegetarian, though what its particular preferences were can only be guessed at.

As for our bees, a process must have operated some time millions of years ago to cause the female ancestor of the honey-bee and the bumble-bee, who would certainly have led a solitary life, to develop a profound change of habit. When bees started to live together in societies it is impossible to say. Nevertheless, no student of insect behaviour doubts that the social bees had solitary ancestors whose females collected nectar and pollen and worked alone, just as the solitary females do today.

It has already been said that the vast majority of known bees belong to the category of the solitary species. For all that, their females, though they maintain their independence, are often extremely gregarious. Certain species nest in immense colonies that go on year after year. Although the burrows are frequently but a few inches apart, each female recognizes her own without difficulty in spite of the proximity of neighbours.

The female produces a small family—a very small family indeed, compared with the total number of individuals that make up the progeny of the social bees. She may leave behind a dozen offspring, but this is a generous estimate.

The smallness of the family need cause no surprise. After all, it is directly connected with the amount of work that the mother bee must perform in providing for her young. The reproduction of the solitary bee does not end, as it does for nearly all other insects, with the mere laying of eggs on or near the food that the young will eat. A simple example will make this clearer. The Large White butterfly is sensitive to the essential odour of a cabbage plant. She lays a batch of eggs on the underside of a leaf and flies away. She can lay a hundred eggs as easily as fifty. With a few such simple acts of egg-laying she accomplishes the whole of her maternal duties. As for the fate of her brood of caterpillars, she has no share in it. But for the solitary bee the matter is arranged differently. Not only must she collect the whole amount of food to be consumed by her offspring, but she has also to prepare a nest to receive it. Later I shall give some examples of the skill she displays in making her nest. At the moment it is enough to say that within it a separate nursery or cell has to be built for each of her young and the right amount of food stored to meet its needs. In view of all this it is not really surprising that the working life of a solitary bee seldom runs to more than a few weeks. It has even been suggested that some of the early spring bees of the genus *Andrena* get through all their work in three or four days, taking fullest advantage of the short and fitful spells of fine weather that come at this time.

The food prepared for the young consists of a mixture of nectar and pollen, commonly called bee-bread. As a rule the pollen is carried on some part of the female's body back to the nest, scraped off into the cell and afterwards moistened with nectar. The name 'bee-bread' is appropriate if the food is dry and crumbly or forms a sticky lump; but quite often it is a thin mixture, more like a batter, containing probably a bigger proportion of nectar. The consistency of the prepared food has nothing to do with the personal competence of the mother. We do not recognize a light touch here and a heavy one there, or any of those signs that mark individual ability. If a certain species of bee makes a firm loaf, then all the females of that species will make their loaves equally firm, for their young can develop only on a prepared diet of a definite quality and texture. If, on the other hand, we find a female storing her cells with a thin, semi-fluid mixture, we know that she belongs to a species that has the habit of preparing its offspring's food in this way.

Since the solitary bee stores in each cell or nursery all the food that a single grub will need for its complete development her method of feeding her young is called mass provisioning.

The honey-bees and the bumble-bees feed their young differently. They do not leave their grubs shut up within cells and provided with a complete supply of food. Instead, they give each grub a kind of personal attention throughout its period of growth, feeding it whenever it is hungry. This is known as the progressive method of feeding the young.

Here we have what looks like an excellent distinction between the solitary and the social bees. It certainly holds for the vast majority of bees, but like some of the other generalizations that I have been tempted to make, it must not be pushed the whole way. There is, for instance, an interesting group of solitary bees in Africa called *Allodape*. Their behaviour, about which we shall learn more later, is so curious that the term 'solitary' loses its meaning when applied to them. The female *Allodape* breaks all the rules by going in for progressive feeding. And again we have only to look into the domestic arrangements of the Stingless bees of the tropics to find that they feed their young by the method of mass provisioning in spite of a social organization hardly less complex than that of the honey-bee, *Apis mellifera*.

Chapter Three

FROM EGG TO ADULT

It is only when the habits of a bee are seen against the background of its complete life cycle that they acquire their fullest meaning. The behaviour of the adult cannot be regarded simply as a pattern of individual modes of self-expression. Almost all that is of special interest in the activities of bees is closely linked with the preparations they make for raising their families. I have already touched on nest-making habits, but this was simply to show that differences in the method of feeding the young lie behind the division of bees into solitary and social forms. So far we have not yet looked into the young bee's nursery and seen what sort of creature it is.

Bees, like most insects, undergo what is called complete metamorphosis. Put more simply, this means that from the egg to the adult or imago, as the adult insect is generally called, the developing insect passes through four stages that are quite unlike each other. First there is the egg. From it there hatches a grub or larva that later becomes a chrysalis, or pupa; and from the pupa there finally emerges the perfect insect or imago. There are other insects, such as grasshoppers and plant-bugs, whose life cycle is not punctuated by these abrupt changes in form. They undergo an incomplete metamorphosis. The young grasshopper leads much the same sort of life as its parents and is not so very different from them in appearance. In fact, a young grasshopper is just a small grasshopper and you have to be an expert on these insects to be able to guess its age.

The egg of a beetle, a butterfly or a bee hatches into a grub or larva. The butterfly grub is the well-known caterpillar, so completely unlike its parents that there is no obvious resemblance between them. Beetle grubs are less well known than caterpillars and just as unlike their parents. Their whereabouts are known only to experienced collectors who learn how to find them in the soil or the wood of trees or in a dozen other situations suitable for their larval development. Of those that pass their lives in the soil, none is more likely to be met with than the fleshy grub of the cockchafer or may-bug. Probably few people are aware that this gross-looking larva with its white, glistening body and shiny, brown head is merely a stage in the genesis of a beetle.

The grubs of bees are even less known than those of beetles. One reason for this is that they pass their entire life in concealment. Each grows to full size in its own separate compartment or cell in the nest constructed by the mother, or, if it is the grub of the honey-bee, in the cells of the comb built by the workers, who, with their close-packed bodies and their readiness to sting, effectively hide it from view.

Since the grub is brought up in a confined space where much movement is neither necessary nor possible, it has no legs. If it belongs to one of the solitary bees, it shares its cramped quarters with its own food supply. To feed, it has merely to stretch out its neck. Or if its mother has prepared a batter instead of the more solid loaf, then the grub lies floating in it and is spared every effort to secure a meal. Needless to say it is absolutely helpless and has no protection save that afforded by the walls of its cell.

Gradually the mixture of nectar and pollen is consumed and transmuted into the living tissues of the grub. But in the metabolic processes of growth there is the normal accumulation of waste products. The elimination of this waste material is dealt with in a way that is characteristic of the grubs of ants, bees and wasps and of many other Hymenoptera as well. The grub has the ability to retain its faeces until growth is complete and then, having no further need of food, expels in a single motion the whole accumulation of waste. There is an obvious advantage in this when we consider that the grub lives in a very confined space where a continual voiding of waste matter might easily contaminate its food supply.

In common with other insects the growing larva moults from time to time. The skin of its body does not grow; it merely stretches to accommodate the ever-increasing volume of tissue within it. When the skin has been tightened to its limit, the larva ceases to feed for a while. During this brief interval of rest intense physical changes take place within its body. A new skin is formed beneath the old one. Even the skin of the head, as anyone who has ever reared a caterpillar will know, is to be cast off after a new one has been grown in its place. As soon as this brand new skin, like a fresh garment, is complete and ready to replace the old one, the grub begins to make a series of rhythmical wave-like motions that flow from the head backwards. The effect of these movements is to draw the old skin tighter and tighter until it splits somewhere near the head and is gradually sloughed off as a crumpled roll of colourless membrane. These skins remain packed one above the other at the bottom of the cell.

How often these moults take place in the growth of a bee larva is not certain, but probably about four or five times would be a safe estimate.

When full-grown, and after having got rid of the dark mass of waste matter in its body, the larva prepares to shed its skin again, this time appearing no more in larval form but as a pupa or chrysalis. The developing bee is now passing through a period of rest. As a pupa it rests quietly within its cell until at the right moment the living substance of its body undergoes a subtle reorganization, and preparations are made for the final and most spectacular transformation of all—the change into a six-legged insect endowed with the power of flight and active movement.

The pupa of a bee is usually white or yellowish white, soft and extremely delicate. Looked at closely, it has the appearance of a mummy in which, however, the shape of the bee to come is unmistakably revealed. Along the side of the body lie the closely-folded legs. The wings, too, show as small pads and the entire structure of the creature is that of the imago or perfect insect. As the time of emergence approaches, the pupa will darken as the adult bee forms beneath the thin, transparent pupal envelope.

The larvae of some bees spin a cocoon before they change into a pupa, and for this purpose they have a silk gland situated just beneath the mouth. The habit of spinning a cocoon was evidently settled a long way back in the evolution of bees, for should a particular species, or rather its larva, be a cocoon-spinner, it turns out, as far as we know, that all its relatives behave in the same way.

Why the larvae of some bees should make a cocoon and others not is a question to which there is no simple answer. At the time of the actual change from larva to pupa the insect is at its weakest, a tasty morsel for any predatory organism, such as a beetle, on the look-out for a meal. It is tempting and natural to regard the cocoon as a device for protecting the naked and vulnerable pupa from its various enemies. But this explanation is perhaps too glib and too human; it overlooks the possibility that the function of a cocoon may be to protect the pupa not so much from hungry prowlers, whether insect, bird, or mammal, as from other inimical forces such as rapid changes in the temperature and fluctuating amounts of humidity in the atmosphere.

The solitary *Andrenas* and *Halicti* that make their nests in the ground prepare nurseries or cells for their young, which, when finished, are simply smooth-walled cavities. Their larvae, tucked away deep in the soil where neither climatic changes nor active enemies can have much effect on them, dispense with cocoons. But when we turn to the leaf-cutter bees, *Megachile*, and the versatile *Osmias*, who also tuck their offspring away, we find that they all make cocoons.

Suppose we look a little more closely at one of these cocoon spinners. There is, for instance, *Osmia rufa,* a common bee in every suburban garden. The female is fond of building her nest in the oddest situations so long as they conform, however roughly, to the definition of a cavity. A keyhole, a crack between two bricks in a wall, or a deserted beetle burrow in an old tree-stump—all serve her maternal instincts equally well. But though she builds with a clay cement a snug cell for each of her offspring, the larvae, nevertheless, spin a cocoon when full grown. It is a very tough cocoon, too, brown, with a little knob or nipple at one end. Picked up between the fingers and gently squeezed, it crackles as though it were made of parchment. When the right moment comes, some ten months after the cocoon was spun, the bee inside bites its way out, breaks through the earthen walls of its cell and escapes into the sunshine and fresh air.

The bees that complete their metamorphosis in the ground are no less well equipped to leave their cells than the *Osmias.* Like them, they use their jaws, patiently digging up to the surface, driven by a powerful urge to leave the cold darkness of their birthplace and seek light and warmth.

Only a short time is spent in the egg and larval stages. As far as the solitary bees are concerned, it is not difficult to suggest a reason for this. The store of food laid in by the mother has to last the grub for the whole period of its growth. As far as we know, nothing is added to make the mixture of nectar and pollen keep for any length of time. Unless eaten quickly, it would soon become hard, mouldy and unpalatable. This urgency to eat the food while it is still fresh vanishes once the grub has become a pupa, so that we find the pupal stage can be short or very long, varying from a few weeks to nearly two years, though for the majority of solitary bees it is not likely to be more than some ten months.

How long, then, does the whole process of growth from egg to adult take? There is no straight answer to this question; everything depends upon the kind of bee. For sheer rapidity of development I doubt whether a queen honey-bee has any rival. From the moment she begins life as an egg just out of her mother's body until she nibbles her way as a fully-fledged virgin queen out of her cell, a bare sixteen days have passed. But these sixteen days have been spent in a high and fairly constant temperature in the neighbourhood of 93° Fahrenheit.

Taken as a whole, the social bees are the quickest to complete their development. The reasons for this will be clear when we come later to consider how their social organizations are geared to fine weather and relatively high temperatures. But for most solitary bees, at any rate those of the temperate regions, the profound changes of metamorphosis are completed much more slowly, and usually a whole year must pass before the egg laid by the female appears in its turn as an insect like its parents.

Even though the development of the solitary bees may take a year to complete, the time spent in each stage of growth is not the same for all kinds of bees. *Anthophora pilipes*, whose black female I mentioned right at the beginning of my story, passes the winter as a resting larva, turns to a pupa the following spring and emerges as an adult a few weeks later. Others, among them the *Andrenas* that come out in the spring, become fully winged bees towards the autumn of the same year and pass the winter, still in their underground cells, in a torpid condition. It is the same with the *Osmia* that made the parchment-like cocoon. If a cocoon is cut open in the winter, the fully mature bee will be found inside, ready to pop out and become quite lively if brought into a warm atmosphere. All these bees will wait until the warmth of the coming spring and summer stirs them into activity.

Although this account of the life cycle is brief and has no other aim that to give the barest essentials, it will, perhaps, have answered one question often asked by people. Does the small bee remain small or does it grow into a larger one? By now it will be clear that the adult is the end product of an organism that starts life as an egg and passes through the intermediate stages of being a larva and a pupa. With the appearance of the adult, growth and structural change have ceased. Wearing its skeleton on the outside and therefore encased within it, the bee cannot add a jot or tittle to its stature. Certainly it looks larger when its crop is full of nectar than when it is empty. But this is a different matter; the bee has not grown, it has merely become inflated.

Chapter Four

STINGS, NECTAR AND POLLEN-BASKETS

There are two things about bees that are firmly fixed in the minds of all of us: first, they sting, and second, they make honey. The bee responsible for these fixed ideas is, of course, *Apis mellifera*, the hive- or honey-bee. It is true that bees, or most of them, feed on the nectar of plants, but to what extent they transform it into honey, as we know it, is not at all clear. For one thing the vast majority of species do not store their nectar separately; they take it back to the nest in their crop, or honey stomach, where it is regurgitated, or vomited up, and mixed with pollen to form a suitable diet for the young. The storing of nectar as honey in special cells designed for the purpose is a habit of the social bees, and these, as I have already pointed out, form only a small fraction of the number of species so far discovered.

That bees sting in the sense that they attack and use their sting as an offensive weapon is again true only of the social species, and even then we must exclude the Stingless bees. As for the solitary bees, they certainly have stings, but for all that they are among the most timid of insects, and I have never heard of them attacking anyone.

The sting of the ants, bees and wasps does naturally put them in rather a special category. They alone furnish us with examples of insects that deliberately attack under provocation. Many beetles, if picked up carelessly, can give a sharp nip that will draw blood. A female stag beetle, for instance, will grip so tightly with her sharp jaws that if you are unlucky enough to get bitten by one you may have to smash her head to get free from the vice-like grip. But such an experience, however painful, would not justify your calling beetles aggressive insects. Even the mosquitoes that come upon us stealthily, betraying themselves only by a low whining hum, have no other purpose than to seek a meal of blood. So it is with their distant relatives, the golden-eyed Chrysops and the soft-footed clegs, Haematopoda—those flies that are abroad on fine summer days and whose persistent biting turns a picnic into a torment. They have no hostile, aggressive impulse to satisfy. It is only a feed of blood they want.

With the social bees and wasps it is a different story. They assault us violently, and, let it be said to their credit, with no thought to their own personal safety. The object of their stinging is to inflict enough pain to deter us from threatening their security. An angry honey-bee will put strong men to flight and it has been said that whole armies have been routed by the fury of hives of bees flung into their midst. I shall never forget once seeing a high-ranking naval officer who neither lacked courage nor was ignorant of real danger dive clean through a privet hedge in an attempt to throw off an angry bee.

It is always the honey-bee that holds the stage when the conversation gets onto the subject of stings. The small size of this little amazon buzzing closely round our head, the speed of her flight and her high-pitched hum, are enough to produce a feeling of panic in any one of us not used to being stung by bees. To an accompaniment of frantically waving arms and all those uncontrolled, fear-inspired movements that ought, in the special circumstances, to be most carefully avoided, the bee is roused to fury. As likely as not she takes a dive into her victim's hair and there continues her shrill buzzing. This is the moment of real terror. The experienced beekeeper is equal to the occasion; he strikes his head hard, hoping that the bee will be killed before she has burrowed down to the scalp and planted her sting. But for others, frightened through unfamiliarity with what they can expect from the sting of a bee, there is no such possibility of escape. They get stung and mistrust all bees for ever afterwards.

A weapon that can inflict pain as effectively as the sting of a honey-bee should surely have some rather special features. As a matter of fact the sting itself is a fairly simple structure. It is made up of three fine needles that fit together in such a way that they enclose a hollow tube or canal. Seen in cross-section the arrangement of the different parts is as follows: above is a single thick needle called the stylet sheath; along its longer edge are a couple of guide rails that hold in place the two finer needles or lancets, each of which has a groove on its upper surface into which the guide rail of the stylet fits. Although the two lancets can be moved a little both backwards and forwards, they are always held in place by the rails of the stylet sheath so that the essential form of the sting as a sharply-pointed instrument is always preserved. At the base of the sting, concealed inside the bee's body, is the poison bag, or pouch. Certain glands pour an acid secretion into it. But before the poison is forced along the hollow sting, another secretion is added to it, this time from an alkaline gland. It is the venom that causes the pain; the prick from the sting itself could hardly be felt.

Two intriguing questions about bees and stings frequently crop up. Is the sting left in and is it true that a bee always dies after stinging? If these questions apply to the honey-bee they can be easily answered.

The sting is finely barbed towards its tip; the barbs or serrations are present on each of its three parts and they point away from the tip like the barb of a fish hook. The bee can drive in its sting easily enough; but pulling it out again is another matter, for now the sting is being gripped tightly by the elasticity of human flesh and held fast as well by its own barbs.

If the bee were left alone, it might perhaps be able to withdraw its sting. But this is asking too much, and in any case fortitude might not be very profitable, for it is more than likely that the longer the bee is stuck fast to your person, the more venom it will inject into a wound that is painful enough already.

One impulse dominates all others; this small insect that violates the integrity of your physical comfort with such cruel pain must be removed as quickly as possible. It is flicked, brushed or scraped off, and at the same time the sting, firmly anchored by its barbs, is torn from the body with all its muscular attachments.

After such mutilation it is inevitable that the bee should die. But, oddly enough, death does not come at once, and the luckless bee, though disabled beyond repair, still has enough vigour left to go on attacking as aggressively as before. The only harm it can do now is to give little nips with its mandibles.

The plain statement that the honey-bee dies after stinging would be rash and untrue. Everything depends on the nature of the victim's flesh. Man is not an enemy of the honey-bee and none could seriously maintain that her sting has been designed for use against him. Nowadays certainly, in an era of enlightened beekeeping, the beekeeper likes to regard himself as the friend of the bee. Sometimes the bee misunderstands his well-meant intentions and is more impressed by his clumsiness than his solicitude for her welfare. Then she turns upon her protector, punishing him unmercifully and at the same time throwing away her life. People are prone to become sentimental about the honey-bee when she stings and dies. They think of her as having sacrificed her life in defence of home and family. This kind of thinking obscures the truth, for the behaviour of a bee, whatever the circumstances, is never determined by emotional considerations.

If man is ruled out as the natural enemy of the honey-bee, against what enemies then is her sting to be used? Where the bee has gone wild, it usually nests in hollow trees, often high up out of reach of mammalian enemies. There are still threats to its security, however, and occasions when it will be called upon to use its sting freely. In a sense the honey-bee is its own enemy. The stores of honey laid up by one colony are coveted by the bees of another, and unless the rightful owners can properly protect what they have so patiently gathered, alien workers will crowd in upon them and plunder their honey. There will be much fighting. The battles are long and intense, as many a beekeeper will know who has been unlucky enough to witness an outbreak of robbing in his own apiary. Bees are stung to death in their thousands, but here is the point I am trying to make: the bee that gets in first with a fatal thrust is able to withdraw her sting eventually, and as far as I can make out without damage to herself. While the fighting is going on a bee can often be seen trailing another after it, held by the tip of the victor's sting. The wounded bee is sooner or later cast off. There must be an explanation for this. The only weak spots in the armour of the bee are the membranous connections between one horny part of the insect's skeleton and another. Possibly the membrane is too thin and too weak to hold the barbed sting against the counter-pull of the victorious bee when she tries to withdraw it.

If a bee is held by its wings against the thumbnail it will be noticed, as the sting darts in and out from the opening at the tail, that a droplet of clear fluid appears at its tip. Nothing was known about the chemical composition of this venom for a long time, though the weight of opinion considered it to be essentially acid in its reaction. Remedies are still sought among alkaline chemicals to neutralize the effects of a bee's sting. Soda, the blue-bag, the juice of an onion, and even the humble dock leaf—all have their staunch adherents. None of these antidotes is really any good because bee venom is not wholly acid but a subtle poison of complex chemistry. It seems that once the poison begins to diffuse, complicated chemical changes take place. One reaction leads to the liberation of the drug histamine. This drug is responsible for some of the unpleasant symptoms that follow on a sting.

There is a common belief that bee venom will cure rheumatism. If it were true, then beekeepers as a body ought to be free from this complaint. But as a matter of fact they suffer from it as much as any other group of people. Certainly there is evidence that the venom has a therapeutic value in relieving some kinds of rheumatism, but that it is a sovereign remedy for rheumatic conditions generally is far from the truth.

The questions relating to stings are really of small consequence when bees as a whole are being considered. For the vast majority of them, though armed with a sting, appear to have no use for it whatever. We can, therefore, leave their stings and see how they obtain their food. To say that bees are strict vegetarians is a fairly safe generalization. There are, of course, the inevitable exceptions, but these, for all their outward appearance, can be disposed of as mere aberrations of behaviour. The honey-bee, for instance, is not above visiting the dung heap for the liquid that seeps out in noisome puddles, and it is recorded that the Stingless bees in South America will feed at the public urinals.

There are no carnivorous bees; nor have they the varied tastes of their distant relatives, the wasps. Plants provide them with all the nourishment they require—nectar to give them persistent energy and pollen to provide them with body-building protein.

Since these plant products are needed by the bees for their young even more than for themselves, the bees must naturally have some means of transporting them back to the nest.

For sucking up the nectar, the bee uses its tongue. This all-important organ is complicated in structure, being made up of several parts that fit together in such a way that they form a tube through which the bee draws up nectar into its mouth just as a child might draw up lemonade through a straw. Some bees have long tongues; others have them quite short. It all depends on the kind of bee. Most of the solitary bees of Great Britain have short tongues, and for this reason tend to visit flowers with shallow corollas whose nectar can be easily reached. The bumble-bees, on the other hand, often have very long tongues, long enough for them to reach the nectar at the bottom of the deep spur-like corolla of the nasturtiums and delphiniums. Visit a clump of delphiniums when they are in full bloom and you will probably see a bumble-bee hovering closely in front of the blue spikes or settling for a moment to push its head into a flower. This is almost certain to be *Bombus hortorum*, a species whose tongue is considerably longer than most.

The nectar swallowed by the bee is temporarily stored in its honey stomach, or crop. This is a dilation of the alimentary canal and lies in the front part of the abdomen. It is separated from the true stomach by a valve. As far as the social bees are concerned, the crop is a kind of factory in which the temporarily stored nectar is changed into honey. Back in its nest the female bee can, at will, force back this nectar, or honey, to its mouth by contracting the muscles of its abdomen and place it wherever needed. The returning honey-bee either deposits her load of nectar directly into the waxen cells, or, as is more usual, passes it on by mouth-to-mouth contact to younger bees which then regurgitate it themselves into the appropriate cells. It is the sugars found in nectar that give bees their energy. Deprived of them, they soon languish and die. Pollen, on the other hand, is the bee's body-building food and is, indeed, the staple diet of their young. We find here what looks like an obvious exception; the larva that eventually becomes a queen honey-bee is fed on a predigested substance called royal jelly, a milky fluid secreted from certain glands in the head of the workers. But even this food is ultimately derived from pollen eaten by the young bees.

It is only the female bee that gathers pollen, an accomplishment that makes her one of the most interesting of all insects. With her loads of pollen she is a pretty object. After all, does she not carry with her the proof of a life dedicated to sober industry and the fulfilment of maternal duty? It is perhaps not surprising that some of her more sentimental admirers have sometimes expressed themselves poetically about her golden thighs.

We may roughly divide into three the ways used by bees to load up onto their body the masses of pollen grains. As the honey-bee is so well known, it might be a good thing to start with her and see how she sets about the matter.

The hind leg of a bee, in addition to the basal part, or coxa, by which it is attached to the trunk, or thorax, is made up of three parts, corresponding roughly to those of the human leg. There is a femur, or thigh, a tibia, or shank, and a tarsus, or foot. It is the middle part, or tibia, with which we are concerned just now. On the outer side of its tibia the honey-bee has a smooth, slightly hollowed-out region, hedged in by long curved bristles. The polished surface with its palisade of bristles forms a basket. It is usual to refer to this modified region of the honey-bee's leg as a pollen basket, or *corbiculum*, to give it the Latin name commonly employed by entomologists.

For a long time the process by which the honey-bee transferred the pollen to its pollen baskets remained a mystery. The bee adopts no hard-and-fast method, but competent observers have now told us how it generally happens. The bee dislodges the pollen grains from the anthers with her tongue and mandibles, at the same time moistening them with honey and saliva so that they hold together. Soon they begin to stick to her legs and body. And much of the dry pollen that she scatters so recklessly in her excitement clings to her also, caught and held amongst the branched hairs of her coat.

The bee now brings her legs into action. With beautifully co-ordinated movements they brush and sweep up the pollen. The grains are first passed, in loose clusters, from the front legs to the middle legs and then on to the hind pair. Here they begin to accumulate on the broadened inner surface of the tarsus. By making use now of structures on the hind legs, which may be likened to brushes and combs, the bee gradually forces the pollen upwards until it reaches a little gap between the tarsus and tibia. Bit by bit it is forced through this gap until finally it passes out on to the smooth surface of the tibia into the pollen basket. Here the swelling lump of pollen is patted and pressed into shape by the middle legs, all the while being held in place by the hairs round the edge of the basket.

This way of gathering pollen is exceptional among bees. It is the method employed by the social bees, all of which

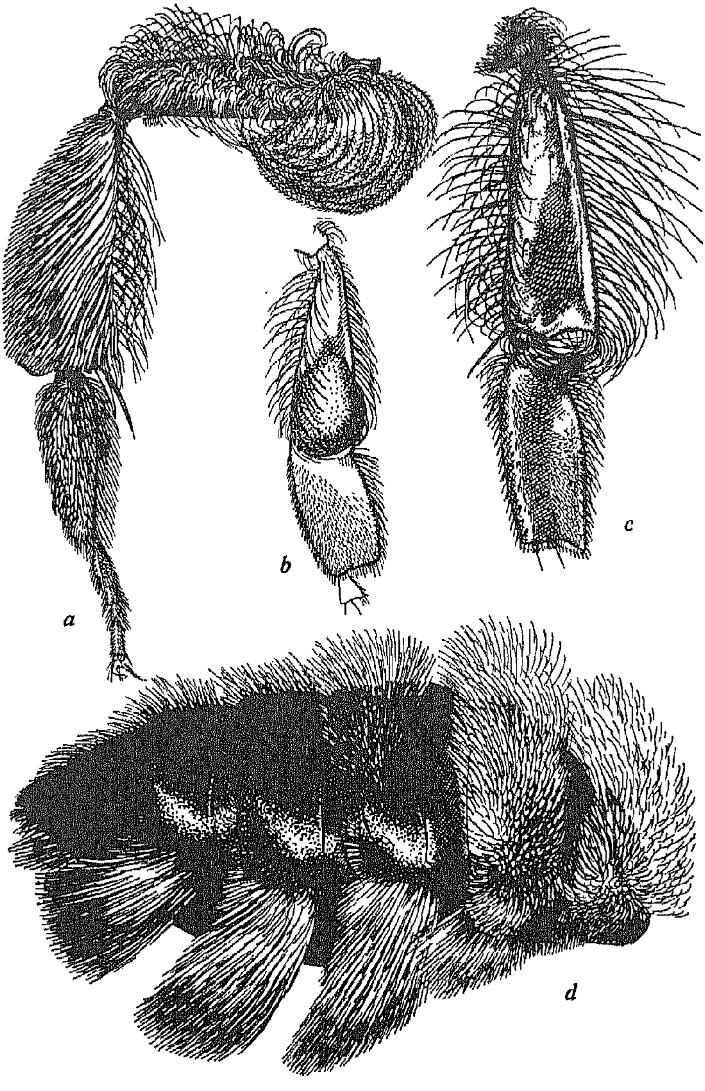

Fig. 2

How bees carry pollen: *a*, among hairs of hind leg (solitary bee, *Andrena*); *b* and *c*, in pollen basket (honey-bee and bumble-bee); *d*, beneath abdomen (solitary bee, *Megachile*) (see page 47)

have a pollen basket similar to that of *Apis*, the honey-bee. The moistening of the pollen grains with nectar or honey is an essential part of the process. Unless this precaution be taken the grains could not be made to stick together and form the characteristic lump.

It is not only pollen that the honey-bee takes home on its hind legs. The baskets are also used for gathering loads of propolis, a gummy, resinous substance that the bees obtain from the sticky buds and shoots of certain trees and use for stopping up cracks in their hive in order to make it as impermeable as possible. This substance is certainly not gathered in the same way as pollen, as I have managed to see for myself.

The top of a hive of bees, beneath the roof, is often covered with a piece of board. If this is removed, it will often have a ridge of propolis around the edge, used by the bees to make a tight fit. Left on top of a hive such a board, with its fragrant smell of propolis and wax fragments, is a great attraction to bees. They will come to it and remove much of the propolis, especially if the weather is warm and the propolis is soft. I have seen bees gather up this substance many times. They pull and tug at the sticky gum with their mandibles, biting off small fragments which they convey by a rapid and skilfully co-ordinated movement of the front and middle legs direct to the pollen basket. There is no question now of using the special brush-and-comb apparatus; the material is much too sticky. When the bee is fully loaded up, the propolis forms a loose ragged-looking lump. It is remarkable that the bee should in some way be aware that she is handling two entirely different kinds of material and that a different method of gathering them into her pollen baskets is necessary.

The solitary bees have simpler ways of collecting pollen; they dispense with the moistening of the grains and prefer to collect their pollen dry. A pollen basket like that of the honey-bee or bumble-bee would be of no use to them, for the powdery pollen would fall out as quickly as it was gathered. As I said earlier, the branched hairs of the honey-bee hold the dry pollen grains that happen to fall on them accidentally. If such hairs are stiffened and placed close together so that they form a dense brush, they would effectively hold the elusive pollen grains. It is a brush of this kind that we find in the solitary bees. Most of them wear it on the hind legs, especially on the tibia, but the femur and coxa of the same legs are also frequently clothed with pollen-holding hairs, though they tend to be longer than those of the tibia and flocculent rather than brush-like.

The *Andrenas* that come out in the spring all collect pollen on their legs. To see how effectively they gather it, one needs only to watch them working at their nests on sunny days. Again and again they return to their burrows, their hind legs yellow with dense masses of pollen. It is remarkable how skilfully these little bees free themselves of their loads. Back in her burrow, the female carefully scrapes or brushes off every scrap of pollen and adds it to the store of food that is accumulating for her young. When she emerges again, prepared for another trip, she looks so spick and span you hardly recognize her as the same insect.

When I was making a collection of bees, it often happened that those I caught were carrying full loads of pollen. On a dead specimen such pollen is a great nuisance for it hides the colour and length of the brush of hairs on the hind tibia—two features of a bee's anatomy that are of great help towards its identification. To clean it off I used to comb the bee's legs with a camel-hair brush. But no matter how much time I spent over this fiddling task, I could never match the skill of the bee. The pollen grains could never be completely brushed out and their presence always spoilt what might otherwise have been a perfect specimen.

Although most of the solitary bees have the apparatus for collecting pollen on the hind legs, there are others that gather it only on the underside of the abdomen. To this group belong the leaf-cutter bees, *Megachile*, and many others, among which the most interesting, because of their nest-making habits, are perhaps the bees of the genus *Osmia.*

In all these bees the overlapping plates, or segments, on the under-surface of the abdomen are fringed with a row of stiff hairs that lie almost flat with each row overlapping a little the one next to it. This brush of hairs is very useful to the female; it enables her to pack so much pollen that, fully loaded, she looks just as if she were bright yellow beneath. Exactly how she transfers the pollen from the flower to her body is not quite clear. Certainly the legs help in the process if only to sweep the grains into convenient heaps. To see one of these bees at work, visit a clump of sweet peas in July and you will stand a good chance of seeing a female gathering pollen. In colour she is just plain brown but her movements are precise and rapid, and give her personality. Later on I shall describe the habits of the leaf-cutter bees, but at the moment it is their method of transporting pollen that concerns us.

It is the more advanced bees that collect pollen on specially modified regions of the body—those that have progressed in evolutionary development. But there are others, regarded as more primitive because they are believed to resemble their ancestors more closely, that have neither basket nor brushes. Since, however, pollen is as essential to them as to all other bees, they are obliged to swallow this important article of their diet and carry it home in their crop, where it becomes mixed with nectar. Back in the nest, the female vomits up the mixture

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straight into the cell previously prepared to receive it. The bees with this curious habit are the *Prosopidae*. In size they are nearly always small, ranging from a quarter to half an inch, and apart from an occasional touch of red, are uniformly black in colour. Another thing that makes them unusual is that they have no noticeable coat of hairs. In fact, they are so bald that they might easily be mistaken for small black wasps.

Bees cannot live without pollen, for, as we have seen, it is the staple diet of their young. Taking them as a whole, we find that they are suitably and efficiently equipped for carrying it. There are, of course, the inevitable exceptions, the parasitic bees that are absolutely without means of gathering pollen, though they are as dependent on it as the rest. With their cuckoo-like habits they have found it more profitable to lay their eggs in the nests of their more industrious relatives rather than forage and build a home themselves. Information about the way in which these cuckoos achieve their ends at the expense of other bees will be given in a later chapter.

Chapter Five

BEES' NESTS AND WHAT THEY ARE MADE OF

When we come to consider the family arrangements of insects we certainly do not get the impression that parents are much concerned for the welfare of their offspring. With a few notable exceptions, preparation for the next generation is a casual affair, requiring from the male no more than a brief moment of indulgence, and from the female simply the choice of a suitable place for her eggs. For instance, butterflies and moths lay their eggs on a plant which the future caterpillars will find palatable; beetles and two-winged flies seek out just those places where their eggs will have the best chance of survival. But beyond this point such insects are not involved in the future of their young. Once the females have given birth, they themselves die; no more is asked of them, and the safety of their descendants is left to chance. There are, of course, the inevitable exceptions. The humble earwig stays with her batch of eggs and later lives with her family of miniature earwigs around her. And then there are the various Scarab beetles whose habits have been so well described by Fabre. *In some species both parents take a* share in preparing an underground home for their young and provisioning it with balls of dung, and in others the female stays with her young until they are full-grown.

All this is changed when we bring the ants, bees and wasps into the picture. I am not going to say that they are less indifferent to the fate of their offspring than other insects; that would be giving too anthropomorphic a twist to the way we try to interpret their behaviour, while at the same time I should be committed to a point of view that would be hard indeed to defend. What raises ants, bees and wasps so much above other insects is that responsibility for the welfare of their young is carried far beyond the mere laying of an egg in a place most favourable to its subsequent development.

Throughout the whole of the Aculeate Hymenoptera we see a larva that is utterly helpless and quite incapable, since it lacks the power of locomotion, of finding its own food. It is therefore necessary that food be brought to it, as we see in the social bees, or that it be placed in contact with the whole of its food supply, as is the habit of the solitary species. Moreover, it must be given proper protection because of its extreme vulnerability.

Among the ants both these needs of the larva are met by the worker ants themselves. For the ants are never kept in cells but are carried around by the workers and placed where conditions best suit their growth. Their food is brought to them also, as and when they are hungry, that is, progressively. As for protection, the grubs have the benefit of the workers' ability to bite or sting. Failing such offensive behaviour the grubs are still protected by the speed with which the workers of certain ant species pick up their charges and rush with them to a place of safety.

Bees and wasps do not carry around their grubs. These stay in one place all their life, and for this reason, perhaps, more elaborate preparations must be made for their safety than is necessary among the ants.

The female bee and the female wasp must both gather or hunt for the food on which their young are reared and afterwards transport it to previously-prepared cells, or nurseries, where it is then distributed according to the needs of each single offspring.

Such a big departure from the pattern of behaviour common to most insects promotes the ants, bees and wasps to a position high above other insects and gives them, as might be expected, considerable prestige. In range and complexity of habit they are the most highly developed of all insects, the élite of the world of six-legged creatures to which they belong.

At this point we must part company with the ants and the wasps—they were brought in only to put the habits of the bees in better perspective—and concentrate on the bees alone.

The bees, in their efforts to make a home for their young, have become miners, masons, carpenters and skilled workers in such varied materials as wax, leaves and flower petals.

Let us start with the wax-makers first; it gives us an opportunity of finding out more about the honey-bee, which is a more lavish user of wax than any other bee. Its newly built comb is a most delicately beautiful object. It has a purity all of its own, and the symmetry of its design has been a source of wonder and admiration throughout the ages.

A single comb is a waxen structure consisting of two sheets of six-sided horizontal cells, arranged back to back with their open ends facing in opposite directions. The base of each cell forms a low three-sided pyramid. Arguments have raged about whether the cells are actually made six-sided by the bees or whether their shape is merely the result of mutual pressure exerted by a large number of cylindrical cells in contact. If the matter has been decided, I am not aware of it. In any case, we can safely leave it to those who are specially interested in the mechanics of comb architecture. What needs to be emphasized is that the wax of which these combs are built is produced from the body of the bee herself and is derived from the nectar she gathers with such perseverance and in such infinitesimal amounts from flowers. Once the sugars in nectar have undergone the chemical changes within the bee's body that transform them into wax, this wax is then secreted as a fluid through pores on the polished surface of certain zones on the ventral segments of her abdomen. As the wax oozes, or is sweated, through the wax plates, it forms a layer that hardens into a thin, almost transparent scale, not unlike the scale of a fish. At the right moment the bee pulls off the scales with her legs and transfers them to her jaws. Here they are chewed to a soft paste ready to be used wherever the waxen structure is in need of repair or expansion. The jaws that first made the wax soft and malleable can now be employed just as expertly to build it up into the walls, thin as paper, that separate one cell from the next.

This use of wax throws into relief the honey-bee's dependence on flowers. Their nectar renders a twofold service, supplying an important part of the bee's diet as well as the material, after much chemical elaboration, out of which its home is built.

There are two conditions that must be correctly balanced if the honey-bee is to function efficiently as a wax-making machine: one, its honey stomach must be filled to bursting with a sugary liquid, whether it be nectar, honey, or just a solution of sugar and water; and two, the temperature needs to be rather high, somewhere between 92° and 97° Fahrenheit.

Although it is usual to think of bees as makers of wax, there are actually very few that do it. It is a faculty of the social bees, of the bumble- and Stingless bees as well as of the true honey-bees, that bear the name of *Apis*. Of these three groups the bumble-bees make the least use of wax and the honey-bees, perhaps, are the most dependent on it. The

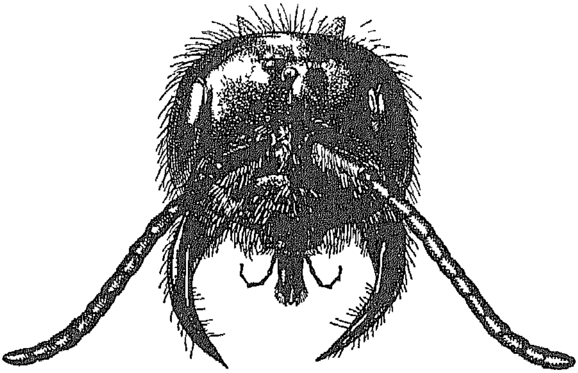
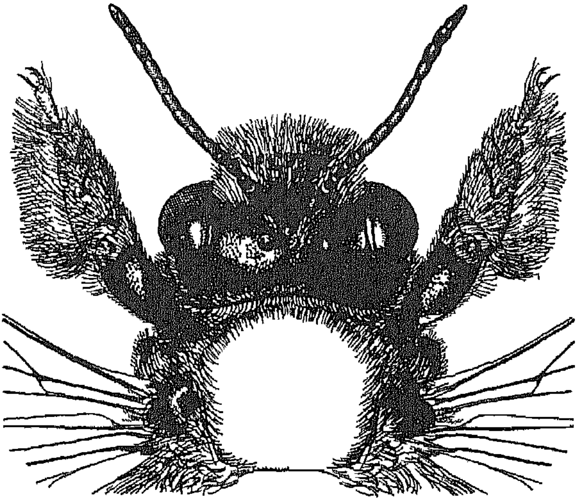


Fig. 3
Head of male solitary bee, *Andrena armata*, to show large sickle-shaped jaws



Male leaf cutter bee, *Megachile willoughbiella*, to show expansions on front tarsus used for holding female at time of mating (see page 22)

common honey-bee, however, requires something more than wax for the completion of its dwelling; it makes much use of the gummy substance called propolis that I mentioned earlier when I described how bees transport their loads of pollen. The propolis is used for plastering cracks in hives, for the honey-bee seems to be very sensitive to draughts. It also serves the interests of hygiene, for should some creature such as a mouse happen to die in the hive and threaten to foul the atmosphere, the bees at once entomb it beneath a layer of propolis.

The Stingless bees produce wax from their own bodies like the honey-bee, but they make fuller use of materials brought in from outside, and in their eager search for these materials they collect a strange assortment of substances. Anything that is sticky or tacky is welcome to them, and they have been known to gather such things as tar, oil and varnish. Many of them even carry away excrement and incorporate it in the structure of their nest. These little bees are forever gathering up something or other, and because of their unsavoury habits fall far short of the ideal commonly held—that bees are cleanly creatures associated with the freshness and purity of flowers.

The solitary bees, whose habits will be described more fully later, find their building material ready to hand as a rule. As they excavate their burrows, usually in the ground but sometimes in wood, there is an accumulation of fine earthen or wood particles. These are cemented together with saliva and used to separate one cell from another or to plug the open end of cells dug singly.

Other solitary species gather their building material away from home and bring it back to the nest. The leaf-cutter bees, for example, line their cells with pieces of leaf and a near relative of theirs, *Anthidium manicatum*, the sole British representative of the genus to which it belongs, prefers the fine down with which certain leaves are covered to the leaves themselves. Still others that journey afield for building material are the mason bees whose habits were described by Fabre with such a wealth of detail. They scrape up fine soil particles, mixing them to a soft cement with saliva or water brought up from the honey stomach.

The common *Osmia rufa* of Great Britain also uses a cement composed of soil, but she gathers the raw material from spots that are thoroughly damp and therefore does not need to add a wetting agent.

Another substance used by the solitary bees is resin, but we have no workers in this material in Great Britain.

Chapter Six

THE HABITS OF BEES: MINERS AND CARPENTERS

If there is one thing about bees that makes a special appeal to us, it is their industry. As this is a virtue we prize highly among ourselves, the bees earn our esteem by displaying it also.

It is perhaps a sobering thought, however, that only the female is really entitled to receive our praise, for her mate can in no sense be looked upon as a model of hardworking virtue. His is a life dedicated to the pursuit of pleasure—a kind of grasshopper existence without cares or responsibilities.

The female, on the other hand, is admirable; she, as the representative of the vast majority of her kind, makes a home, fetches and carries and seeks no other satisfaction in her busy life than the fulfilment of her maternal duties. There is nothing surprising in our thinking more kindly about bees than other insects. Who, indeed, is repelled or frightened at the sight of a big queen bumble-bee working at the flowers of a currant or gooseberry bush in the spring? Behind her hurried scramble from blossom to blossom there seem to lie a sense and purpose, a kind of grim determination that strikes a responsive chord within ourselves so that we watch the burly, homely bee with a warm and friendly indulgence.

Contrast the different attitudes of people towards the peace-loving wasps and the peppery honey-bee. They will run in fear from the bee, but nevertheless forbear to kill it. Killing a bee is like killing a bird; an act that gives one a vague feeling of having committed a crime. But the wasp is fair game for all; she—for the autocracy of the female is a feature of wasps as well as bees—may be pursued relentlessly and with full permission.

If she can be ambushed and struck down, so much the better. Who, in any case, would dream of giving a wasp even a sporting chance? It is one of the most maligned of insects yet does little to deserve the evil reputation so lightly fastened upon it.

But let us return to our bees. Already I have described the various ways in which they gather pollen, and how, mixing it with a variable amount of nectar or honey, they use it for provisioning their cells. I have also said something about the materials employed by the bees to construct their nests. What we need to do now is to see how they actually use these materials.

The whole pattern of behaviour of the solitary bees is, generally speaking, simpler than that of the social groups. In nest-building skill, however, they do not lag behind. It might almost be said that the social bees show less ingenuity and variation in nest construction than their solitary cousins. The comb of the honey-bee marks the peak of their architectural skill. But for all its beauty there is a simplicity about its design that gives it almost a machine-made quality. The cells of some of the solitary bees, on the other hand, are little masterpieces of craftsmanship.

The insistent claim that the social bees make on our attention rests essentially on their complex social organizations; it is the way they run their societies that has always intrigued and baffled us; their dwellings have attracted attention for so long that they are no longer a novelty. The comb of the honey-bee has been known from time immemorial, but our knowledge of the mud cells of *Osmia*, or the leaf cells of *Megachile*, is recent enough to have all the charm and freshness of a new discovery.

The solitary bees show great variety both in their choice of a nesting site and the manner in which they prepare the nest. But let there be no misunderstanding here. A particular species of bee will always make exactly the same kind of nest as that in which it passed its youth. Its behaviour is instinctive in the sense that the series of actions it performs in order to satisfy its building urge follows a set pattern determined a very long time ago. The bee does not need to learn by a process of trial and error how she should build her nest, though it is, of course, conceivable that she may learn to improve some particular technique. One thing is certain: if our solitary bee is a worker in mud, she will certainly not change over to leaves. Nevertheless, there is still room for flexibility of behaviour, and some bees, especially the species of *Osmia*, are very adaptable in their choice of a nesting site. Some females require merely a suitable cavity. Subdividing it by means of clay walls or partitions, they can adapt it to their needs.

The simplest kind of nest is made in the ground. Using her jaws as digging tools, the bee sinks a shaft into the soil, piling up the particles of earth around the mouth of the burrow, so that they form a small mound or crater. The preliminary piece of work finished, she sets about making the first cell. This may be simply an oval hollow dug horizontally off the vertical shaft or it may be the end of the shaft itself, suitably enlarged. The wall of the cell is rubbed down and made smooth. Some bees, such as *Colletes*, even go so far as to varnish the walls with a saliva that dries to form a waterproof skin.

The mother bee now gathers as much pollen and nectar as is needed by a single offspring and stocks her cell with it. How does she know just when to stop laying in her store of provisions? If it sometimes happens that she has been over-generous, it seems that she rarely errs in providing too little. The bees that in due course emerge from her cells will be in all respects like one or the other of their parents.

The storing of the nest with food is not always a straightforward operation; flowers may abound and be within easy reach, but unless the sun shines the solitary bees will be most reluctant to go foraging. Should the weather take a turn for the worse, they are held prisoners in their burrows until the bright light and warmth of the sun return to rouse them from their torpor. Unless the change comes quickly, the bees may die before they have had a chance to complete their nests. And yet, in spite of their dependence on good weather, enough of them manage to get through their work to make certain their reappearance the next season.

The bees of the genus *Andrena* are the harbingers of spring. When they appear it is time to forget the winter and welcome the promise of new life that comes with their arrival. The beginning of March is not too early for some of them. On those cold bright days that are March at its best you can often see the females busily gathering loads of pollen from the yellow sallow catkins. I always feel sorry for them and wonder what twist of evolution let them live so precariously. Friese, a great authority on bees, thought that these early *Andrenas* could get through the whole of their nest-making in a matter of four days or so. Certainly spells of fine weather as long as this do often grace the early days of spring. The *Andrenas* have evidently been well equipped by nature to take the fullest advantage of them.

I have put some emphasis on the struggles of the solitary bees against the vagaries of climate in order to show that there is a fine balance between their way of life and the features, whether harsh or gentle, of their environment.

When all goes well and the mother bee is not interrupted in her labours, she soon furnishes her first cell with the correct amount of food. Her next action is to lay an egg on the bee-bread and to follow this up with the closing of the cell. Fine particles of soil kneaded together and possibly mixed with saliva are used to plug or seal up its opening. As soon as the first cell has been finished, others like it are added until the female has exhausted her supply of eggs or some accident has befallen her.

By this time she is pretty well worn out, and as her labours come to an end she shows all the signs of strain and hard work. Her wings are sadly frayed; the bright colours of her coat have faded, and its hairs have got rubbed off, leaving her with a shiny, threadbare look. Altogether there is not much to remind us of the elegant little bee that originally settled down to make a home.

Most of the solitary bees make nests of this simple type in the ground. It is the rule among such huge groups of bees as those that make up the genera *Andrena* and *Halictus*. In Europe alone there are nearly two hundred different kinds of *Andrena* and even more of *Halictus*. One of the commonest of our British *Andrenas* is the species already referred to as *armata*. It happens also to be one of the most showy because of its female's thick velvety coat of red hair. Sometimes known as the lawn bee, *Andrena armata* is very fond of burrowing into the short turf of a well-kept lawn, much to the annoyance of its owner, who often becomes very worried about the little mounds of earth thrown up by the bee. Hardly a spring passes without someone writing to me about these mysterious mounds that appear, as if by magic, all over some stretch of lawn or other, and of their connection with the red bees that pop in and out of the little hole in the middle.

From the work of the miners we pass to that of the carpenters. It is not a big step to take, for the bees that drill their burrows in wood are not behaving very differently from those that dig them in the ground. The small bees of the genus *Ceratina,* of which one species occurs in Great Britain, seem always to prefer carpentry to mining. The female of our British species likes to make her nest inside dried bramble stems. She seeks out a stem with a broken end, and gnawing through the soft pith at the centre, clears a gallery long enough to house her future family. The end of the gallery becomes the first cell. It is suitably provisioned, and receives a single egg. The mother then seals off the cell with a kind of vegetable cement made from wood raspings mixed with saliva and starts work on another one. The finished nest is hence a series of cells in a row with the oldest larvae furthest away from the tunnel entrance.

Ceratina is by no means the only user of the bramble stems. Besides making suitable nesting places for many small solitary wasps, they are sought out by the black *Prosopis* bees referred to earlier. Strictly speaking we cannot, on the evidence available, call these wasp-like bees carpenters for it seems that they do not make their own galleries but take over existing ones and adapt them to their needs. The deserted burrow of a *Ceratina* makes an ideal dwelling. The female *Prosopis* will clean it out and use it for her nest, but it seems that she lacks the ability to drill or bore a tunnel of her own.

I have already mentioned the habit *Prosopis* has of swallowing pollen along with nectar and vomiting it up as a ready-made mixture suitable for nourishing her young. Obviously the storing of such a fluid mixture has its own special difficulties. The bee must find some way of confining it within the cells so that it is not absorbed by their porous walls. She is quite equal to the occasion and we find that

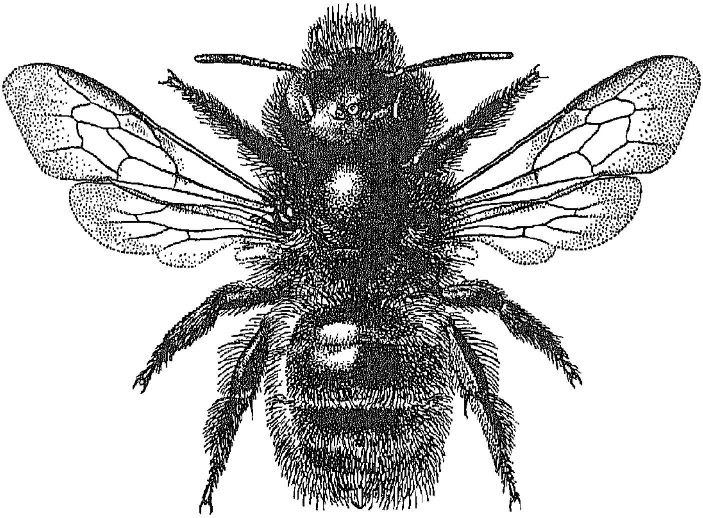
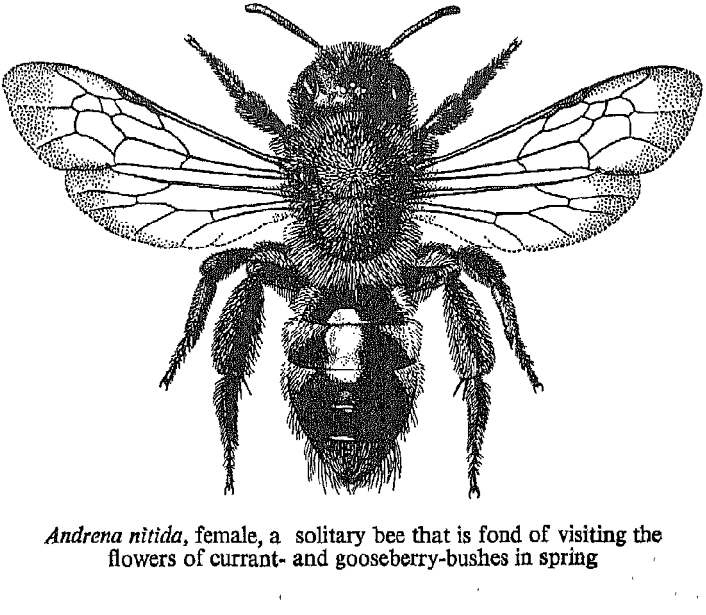


Fig. 4

Osmia rufa, female, a solitary bee (see page 71)



Andrena nitida, female, a solitary bee that is fond of visiting the flowers of currant- and gooseberry-bushes in spring

she possesses a second habit that neatly offsets the disadvantages of feeding her progeny on a thin gruel of nectar and pollen. Using her tongue as a varnishing brush, *Prosopis* lines her burrow with a saliva that hardens as a waterproof skin. She makes the dividing walls between the cells from the same secretion also, so that when the nest is finished the cells are like so many cellophane bags arranged in a row with the bottom of one forming the closed mouth of the one behind it.

In a sense *Prosopis* spins a kind of cocoon for each of her offspring. If the transparent membrane is examined with a lens it is seen to have a texture of countless closely-woven threads. Each of these threads represents a stroke of the bee's tongue as she spreads her saliva. The saliva hardens at once just as the liquid secretion from the spinning gland of a caterpillar dries on contact with the air to form the silk out of which it spins its cocoon.

From what I have said, it is clear that *Prosopis* is no carpenter, if the word is too narrowly defined. She is, however, worthy of special mention because of her remarkable habit of lining and closing her cells with a substance elaborated within her own body. She is not alone in this respect, for her nearest relatives, the hairy bees of the genus *Colletes*, have a similar habit. But these bees have advanced a little further than the more primitive *Prosopis* because their females are able to dig their own earthen burrows.

Of all the bees that make their nests in wood, none do it more expertly than the true carpenter bees. They are known scientifically as *Xylocopa*, which means 'wood-cutters'. They are the giants of the bee world, surpassing in size even the largest bumble-bees. There is nothing in the least streamlined about them. On the contrary, they have a heavy, clumsy look. As for their colour, the females, at any rate, are nearly always black, adorned perhaps with a pair of white or yellow bands. The males, on the other hand, are strikingly different from the females as a rule, and frequently wear a greenish yellow pelt that makes them look as if they had nothing whatever to do with their mates.

The *Xylocopas* are warmth-loving bees and it is in the tropics, especially of Africa and South America, that they are truly at home. Very few of them have extended as far north as Europe, but one species, *Xylocopa violacea*, jet black with deep violet wings, occurs near Paris. This bee is said to be very fond of visiting the flowers of wistaria.

There are several things that are rather odd about these carpenter bees. For one thing, both sexes of the European species, *violacea*, emerge from their cells at the end of summer and instead of pairing at once, like most bees, they go into hibernation and put off the act of mating until the following spring.

An American entomologist, Phil Rau, has written a delightful account of the habits of one of these bees that occurs in the Southern states of North America. He watched a colony of them as they nested in the beams of a wooden shack. From the time they crawled from their wooden tunnels in the spring until the next generation appeared at the end of summer, Rau observed, with what I can only describe as loving enthusiasm, the activities of these burly, homely bees.

Like its European relatives, the North American species emerges from its winter quarters in the spring, and males and females are about in April. According to Rau, it takes a few weeks for the female to settle down to the business of making a nest. But by May work has begun in earnest and now the bees spend the whole day either drilling new tunnels into the wood, enlarging existing ones, or bringing in supplies of food. Since the bee herself is a large creature, the loaf of bee-bread that must be prepared for each of her progeny is correspondingly big. Her egg, too, is decidedly an outsize in bee eggs, being nearly half an inch long. The large egg gave Rau the idea that perhaps the females of this particular species of *Xylocopa* had a low fecundity and he doubted whether, in the course of the season, they ever provided for more than six or eight young.

After their hard day's work, the industrious mothers spent the night in their galleries. The males also were devoted to the place of their birth and would roost at night, huddled together in some crack or crevice.

Another unusual thing about this bee is that the males live almost as long as the females. This may, of course, be a feature of all the carpenter bees; we do not yet know. But normally we find that the life of the male bee is short and hectic. Once he has found a female and passed on to her the fertilizing fluid that he carries in his body, there is no further use for him and he soon dies. In contrast with this, the North American *Xylocopa* males continued to live throughout the summer and pester the females with their attentions long after mating had taken place. They receive no encouragement; indeed, the staid and hardworking matrons become so absorbed in their maternal duties that they express a most vigorous resentment if, returning heavily laden with pollen, they are accosted by some male in the mood for dallying. A female with whom such a liberty was taken would be roused to a kind of fury. She would swoop upon the frivolous male, but he, as though suddenly realizing that this was no warm response to his flirting, would make off in a flash.

There was one stage in the life history of these carpenter bees that particularly impressed Rau. It was what he called their juvenile life. A bee is adult, as we know, from the moment it emerges from a pupa. It may not be physiologically mature, but as far as its anatomy goes it has completed its growth. The pedant may want to quarrel with this statement and hasten to inform me that the ripening of the eggs in the ovary should surely count as growth. On this point I am going to ask the reader to show his indulgence and accept the statement that the bee has reached the end of its structural development as soon as it has sloughed its pupal envelope. This makes it possible for us to see Rau's point of view.

Rau's juvenile *Xylocopas* are young in function, not in appearance. They have emerged from their cells in the late summer, fresh, active and fully equipped to meet the complications of adult life. But what has lured them from the security of their nurseries, since six months must pass before they take on the responsibilities of parenthood? Rau offers no answer. He just accepts the fact and proceeds to tell us what is interesting about it. In the behaviour of the young bees at this time there are traces of some kind of organized social life. Whereas in the following spring they will act as individuals, though living gregariously, they now show some form of co-operation. Most of the juveniles stay indoors, as many as fifteen crowding together in a single burrow. But some of them venture forth on foraging expeditions, bringing back nectar and pollen for the use, so Rau considers, of their companions. Rau thinks the pollen is required by the bees so that they can build up reserves of fat to carry them through their long winter sleep. Another interesting thing about these juveniles is that there is no sex discrimination among them, males and females huddling together in perfect harmony.

The story of this North American carpenter bee—*Xylocopa virginica*, to give it its full name—is important, because it gives us a piece of evidence with which we can close some of the gaps in our knowledge of bees. Already I have shown that bees are classed as social or solitary according to their behaviour. It is a far cry from the labours of some small solitary bee making her nest in a sandbank to the bustle of the highly integrated society of the honey-bee. But looking at bees as a whole, we do not find they fall neatly into the two categories. There are the beginnings of social life in the habits of many of the solitary species. Rau's carpenter bee is only one such example.

So much for the miners and carpenters. The materials they use in nest-making are ready to hand; they are, in fact, a by-product of the work done by the females in making their original excavations. Why could not evolution have stopped here and the solitary bees have stayed content with their simple burrows in soil or wood? This, I know, is a rhetorical question I ought never to have asked, for there is no answer. We accept the diversity of form and function in nature, though we cannot presume to understand all the processes that, over an immensely long period of time, have produced it.

The habits of the solitary bees have not stopped at the digging and drilling stage. Some of these bees have advanced further, and having chosen an existing nesting site, such as a deserted burrow, or tunnelled one for themselves, they bring in material from outside to make each individual cell. The species that show this extra skill are chiefly those that collect pollen on the underside of the abdomen. They are known as the *Megachilidae*, a very large family to which belong the mason bees, the leaf-cutters, and many others for which there is no popular name.

Chapter Seven

THE HABITS OF BEES (CONTD.): MASONS AND PLASTERERS

THE mason bees were favourites of the celebrated Fabre; *Chalcidoma muraria* is the name of the species he studied in most detail. It likes to build its nest fully exposed on the face of a wall or on the large stones or cobbles sometimes found on river banks. The rough material of its mortar is dry calcareous matter scraped up from the surface of roads or paths. The particles are moistened with saliva and kneaded by the bee to a soft lump of putty that she can work with her jaws. As each cell is built up the female embeds small pebbles in its outside wall. This, so Fabre says, is to give it added strength. The bee, however, is careful to plaster the inner surface with a cement of finer texture. The completed cells stand upright and *Chalcidoma* stores them with a viscous honey-like substance in which there seems to be but little pollen. Perhaps a dozen of these cells are built, each the outward sign of an immense expenditure of energy.

Now comes the final effort. The bee sets about enclosing the entire group of cells in a mass of clay. When her task is really finished the nest has roughly the shape of half an orange. It is a solid piece of masonry, finished off with a protective layer of extremely hard cement that is fully able to withstand the effects of weather. Immured within it, the offspring grow to maturity safe from harm.

Fabre's mason bees are not found as far North as Great

Britain, and we have no native bees that make nests of the same design. This does not mean that we are without workers in cement, for several members of the genus *Osmia* are found in our country and some of them make clever use of earthen materials for their nests. One of the largest and brightest of them is *Osmia rufa*, a bee I mentioned earlier in connection with its habit, as a larva, of spinning a cocoon. Its size is roughly equal to that of the honey-bee and its abdomen is clothed with long reddish hair.

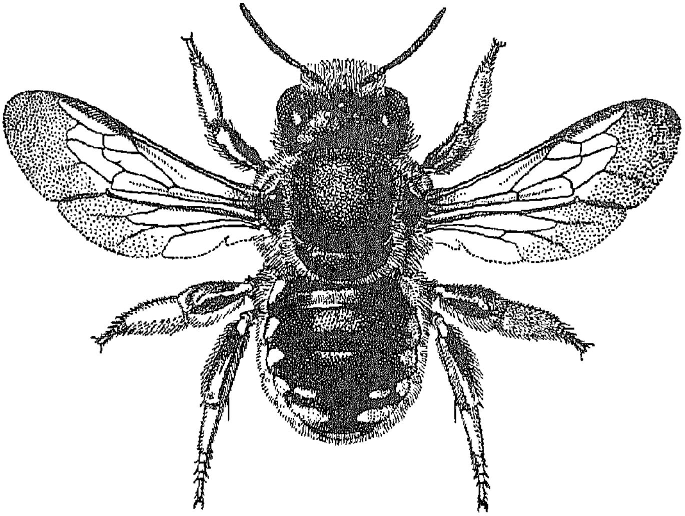
The female requires little more from her varied nesting sites than that they should provide a floor and a ceiling with the right amount of space between them; the walls she can build herself. Unlike her distant cousin, the mason bee, *Osmia rufa* scrapes up damp soil for making her cement or mortar. On the clay soil of the London garden where I first made observations on bees there were damp sheltered spots where I regularly saw two or three females at a time gathering their loads of clay in fine May weather.

As well as being very adaptable in the choice of a home, this particular bee also shows considerable flexibility in the actual way she builds her cells. Should the site be a deserted insect burrow, the cells are arranged in a row with a clay partition between each of them. But if the female nests in a narrow space between wide surfaces, then the cells are arranged like so many apartments on one floor and all in one plane.

I have a particular reason for remembering how fond *Osmia rufa* is of using the burrows made by other insects. At the end of the garden in which I spent so much of my childhood was the railway. Its banks abounded in insect treasures and about half a mile down the line was a dying poplar that had been severely mined by the large caterpillars of the Goat moth. Many of the burrows were stopped with a clay plug that betrayed the work of *Osmia*. Here was a splendid chance to breed a fine series of the bees for my collection if only I could dig out the cocoons. But this would have been a long, slow job that sooner or later would have attracted unwelcome attention, for the tree was growing right on the edge of the track. It had, however, been lopped often and was now just a trunk, no more than six feet high and almost dead. If pushed, it rocked, and this gave me an idea. I decided to steal it from the railway company, by night of course, and drag it home with its precious content. It did not take much rocking to make it fall to the ground with a heavy thud.

On the way back, rolling the trunk on the rails, I suddenly saw two figures coming towards me out of the darkness. Thoroughly scared, I dragged the log to the side of the track and slipped away amongst some bushes. But voices hailed me and I knew they belonged to my own home, where my absence was causing anxiety. There were now three of us to do the transporting and it was not long before my log and all its inhabitants were safely lying on the garden path.

Osmia rufa, for all the anxiety it caused me on that night, is one of the more modest members of a brilliant company of nest-makers. There is nothing especially remarkable about her mud cells, nor, beyond choosing a rainproof cavity, does she take special precautions to protect them. For us just now, this particular bee's claim to attention rests on the simple fact that she brings her building material from outside and thus has advanced a little beyond the miners and carpenters. But elaboration in nest-making among solitary bees does not end with the earthen nest of *Chalcidoma muraria* or the mud cells of *Osmia rufa*, even if the latter do bear witness to a certain degree of improvisation on the part of the female. Her work is a point of departure from which skill in cell construction advances

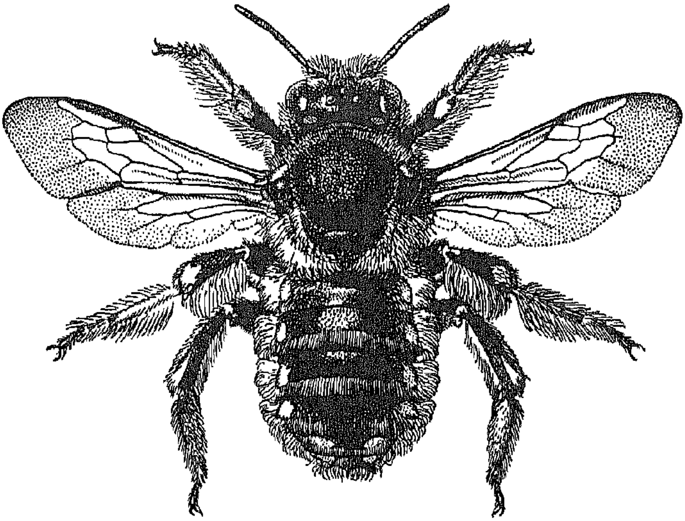


Female

Fig. 5

Anthidium manicatum, a solitary bee (see page 84)

Male



to a stage where we are forced to sit back and marvel that the behaviour of a bee could be so complicated and yet at the same time be directed by the blind force that we loosely call instinct. For if we leave *Osmia rufa* and turn to some of the other *Osmias*, we find them exhibiting techniques in building that leave her far behind.

It is certainly not their appearance that increases any claim to distinction that these bees have. For one thing, they tend to be rather small, hovering around three-quarters of an inch in length, and taken by and large sober in adornment to the point of being drab. Just occasionally they burst out in pleasing colours. *Osmia aurulenta*, before it fades, is a warm red-brown, quite one of the prettiest of them; I remember how thrilled I was when I saw it in plenty visiting the thick clumps of yellow trefoil on the cliffs at Ventnor in the Isle of Wight. And another, *Osmia bicolor*, fond of the chalk downs of Southern England, is a charming little bee with black hairy head and thorax and bright red abdomen.

But here, in the pages of a book, the colours of a bee, however bright, do not mean very much. It is to the habits of the *Osmias* that we must turn to see what it is that puts them in the vanguard of the solitary bees. Here we find a rich mosaic of building skill and a complete absence of the uniformity that stamps the behaviour of such bees, for instance, as the earth-dwelling *Andrenas*. Even the work of the honey-bee, the pale perfection of newly-built comb, so often regarded by admirers in lyrical mood as the highest expression of insect art, seems monotonous in comparison with the architectural ingenuity of the *Osmias*.

There is no obvious connection between snails and bees. But snails die, and when their bodies have disappeared through the natural processes of decay there is left behind the shell—strong, roomy and waterproof. In fact, just the kind of cavity to appeal to the home-making urge of an *Osmia.* So attractive are these empty shells to the bees that there is a whole series of species that choose them to be the cradles of their young in preference to any other kind of nesting site. The habit of using snail shells has become so firmly fixed in these particular species that you will not find them except in those places where the right kind of snails are found also.

Solitary bees are shy creatures. You cannot put them in a hive and study their private life as you would the honey-bee. They must be seen at work in their native haunts. Even this is not enough, for very few of us have the patience for prolonged observation and fewer still the ability to record accurately what has been seen.

A French entomologist of the name of Charles Ferton possessed these qualities in the fullest measure. His interest in the habits of bees and wasps was almost a passion; although a soldier by profession, he refused promotion at one stage of his career in order to remain in Corsica, where he was stationed, and continue his observations on their behaviour.

The writings of Ferton have none of the brilliance of the great Fabre. He is no spellbinder and is content to record quite simply what he sees, letting the facts speak for themselves. The snail-loving *Osmias* came within range of his sharp vision, and he has left behind a series of observations on their habits that are extremely rich in detail and full of interest.

Suppose we go first to Algiers, where Ferton watched many different bees at work, and see *Osmia fossoria* making her home on the hot, bare sand. She has found an empty shell, just big enough for conversion into a single cell. Like all the helicophilous *Osmias,* she uses a vegetable cement, made of leafy material chewed to a paste, for blocking the open end of the shell after she has stored it with a semi-liquid batter of nectar and pollen and laid her egg. So far her behaviour shows no special feature. Except that she has used a different kind of cement—one of vegetable instead of mineral origin—she has made and provisioned her cell like the majority of solitary bees. But whereas her northern relative, *rufa*, hides many cells in some cavity, the single cell of *fossoria* is so far concealed only within the frail walls of an abandoned snail shell, lying fully exposed on the hot sand, where it could be crushed under the foot of some passing animal, or its cement softened and washed out by winter rains.

It would be silly to say that the mother foresees all the dangers. What goes on in a bee's brain is still very much of a mystery, except when some impulse or other is translated into an action that we can see and perhaps measure. But in the behaviour of *Osmia fossoria* one thing is certain: the bee's work does not end with the mere provisioning and sealing of the cell. There is more to be done to the shell before it is abandoned to the hazards of chance. The mother covers it entirely with a kind of rough cast, using small pieces of broken shell glued together with a cement made of finely chewed plant particles. Sometimes the bee prepares her cement from the petals of a blue flower and then its colour, so Ferton tells us, makes a happy marriage with the dazzling whiteness of the shell fragments.

Thus, by increasing artificially the thickness of the snail shell, *Osmia fossoria* strengthens the walls of her cell. But even now she is not satisfied. The shell must be buried. The bee is no skilled digger; she takes hours to dig a shallow hole while *Ammophila* the sand wasp, working a short distance away, has a burrow ready for her progeny in a matter of minutes. At last the bee's work is done and now, walking backwards all the time, she pulls and rolls the shell until it tumbles into the hole made to receive it. She then shovels back the sand, but Ferton finds that she takes very little trouble over this part of her task, and shows none of the efficiency of the sand wasps that conceal so faultlessly the whereabouts of their burrows.

Suppose we compare the habits of *Osmia fossoria* with another snail-loving *Osmia* that occurs also in the Mediterranean region. Her name is *rufohirta* and she, too, according to Ferton, makes a single cell in a small shell. This mother is faced with the same problem as the *fossoria* female. How can the fragility of the shell be offset and that extra amount of protection be given to the bee's offspring? *Osmia rufohirta* does not bury the shell; she is content to roll it to a safe place, hiding it perhaps beneath a tussock of grass. She also adds something to the outside of the shell, though it is only a thin patchy coating of finely-chewed vegetable fragments mixed to a paste with saliva. It is hardly thick enough to strengthen the shell, and its function, so Ferton thought, is probably to give the bee a foothold. She can hold onto its rough surface with her claws and thus drag it along more easily.

Some species of *Osmia* make a habit of burying their shell, others are content to roll it to a place of safety. But in either case the shell needs to be small, for otherwise the mother bee would not be able to move it; and because of its small size it cannot be converted into a nursery for more than a single baby. Other *Osmias* economize in labour by using larger shells and building several cells in them. Our British *Osmia bicolor* is one of these. But she, like her relatives in the warmer south, goes to a lot of trouble to conceal the shell. Moving it is out of the question: it is much too heavy, with its several cells, for the frail strength of the bee. So she covers it with wisps of dried grass and even pine needles, gluing the whole together until the shell is completely hidden beneath a little tent of vegetable debris.

In describing some of the habits of the *Osmias* I have been concerned chiefly with their ingenious methods of hiding the completed nest. But before we leave these clever bees I must say a word about their choice of building materials, for here we find an approach to the habits of the leaf-cutter bees, *Megachile.*

Just as there is a whole group of *Osmias* utilizing empty snail shells in the construction of their nests, so are there several different kinds that line their cells with the petals of flowers. These, according to Ferton, show a preference for red flowers. He studied one of them, *Osmia cristata,* in the south of France and from his account of its habits it seems that this bee displays an unusually wide range of aptitudes. *Osmia cristata* visits the blossoms of the mallow, *Malva sylvestris.* She alights on a flower and rolls up a petal just as easily as we might roll up a piece of tissue paper. Back home—a simple burrow in the ground—the bee spreads out the petal over the wall of the cell and continues to paper it with petals until there are two or three thicknesses of them. After storing a semi-liquid honey in which her egg floats, the female closes the cell with more petals, using five or six layers this time. And this is not the end of the operation, for she then spreads a double layer of vegetable cement over the plug of petals, to give the cells further protection.

The great charm of the *Osmias* resides in the diversity of their habits; there is a refreshing variation not only in the choice of a nesting site and the attempts to conceal the finished nest, but also in the bees' use of vegetable and mineral substances for making the all-important mortar. It is doubtful indeed if there are any bees that outstrip the *Osmias* in building skill. They have their rivals, of course, as we shall see when we take a look at some of the homes that the leaf-cutter bees make for themselves.

Chapter Eight

LEAF-CUTTER BEES

THE leaf-cutter bees, known scientifically as *Megachile*, are specialists in the art of using pieces of leaf for making their cells. We are already familiar with this habit of papering the walls of a cell; *Osmia cristata* has shown us how neatly a bee can do it with petals; *Megachile* is no less skilful with her pieces of leaf. It is possible that *Megachile* in her dependence upon leaves rather than petals has advanced a stage further in the evolution of nest-making habits than *Osmia*. The petals of a flower are, after all, so much a part of the bee's source of food; they are the signpost that attracts in the first place and then becomes the alighting-board from which the eager bee visitor reaches out to the pollen, or brushes past the organs, on which it is born, to the nectaries beyond. How it came about that some bees first began to bite off the petals of flowers and use them for lining their cells we can only conjecture. But the probability exists, I think, that they took to the petals first because they were naturally in constant contact with them. Later they learnt that equally good use could be made of the leaves.

There are hundreds of different kinds of leaf-cutter bees and they occur all over the world. In the tropics they come forth in their showiest colours. There is a little species in New Guinea that is a thing of exquisite beauty; its prevailing colour is a jet, velvety black, but the head is sharply contrasted in white and the tail is picked out in red.

Sober, indeed, are the pelts of its relatives in Great Britain by comparison. Of these, however, we do at least know something of the habits, whereas of the ways of the elegantly-clad New Guinea species we know nothing.

The British leaf-cutter bees are out in June and July. The females require a burrow in which to make their cells. Some species make one themselves; others are content to use the deserted burrow of some other insect such as a beetle, or any tunnel-like cavity, such as a hole in a wall or some narrow space in a piece of woodwork. The choice depends on the species of bee. *Megachile maritima*, for instance, always makes a burrow in sandy soil, whereas *Megachile willoughbiella* likes to bore into the rotten wood of an old tree stump. Willows are an especial favourite. Such preferences, however, are really apart from the main issue, which is to see how the bees make their cells.

The female cuts pieces of leaf of two sizes, the larger size for lining the walls and the smaller for plugging the ends. Now, when she goes off to fetch her material she must surely have decided beforehand on which of the two sizes she needs at that moment. Whether her action follows some kind of reasoning or not, I do not know. Although I consider bees to be among the most wonderful of all insects, I hesitate to grant them even the smallest degree of intelligence. I can therefore make no positive assertion on this feature of the leaf-cutter bee's behaviour, only offer you the facts and leave you to draw your own conclusions.

The female flies to a rose bush or a virginia creeper. For some reason she is particularly fond of these plants, though she makes use of several others as well. Clasping the edge of a leaf, or rather straddling it with her legs, she rapidly cuts out a large piece with a scissor-like motion of her powerful jaws and flies off home with it. Here she arranges the larger pieces in such a way that, with each slightly overlapping the next, they form the walls of a cell. As soon as these walls or sides are finished the mother makes a bottom to the cell with a wad of smaller circular pieces of leaf. She then stocks it with food—a somewhat thin mixture of nectar and pollen on which she finally lays an egg. It only remains now for her to plug the open end with more circular pieces of leaf. On the completion of this operation she has fulfilled the task of providing for the welfare of a single offspring.

Other cells are then built, and such is their arrangement that the plugged and slightly countersunk mouth of the first becomes the base of the second, and so on until the bee has made a row of them, perhaps as many as a dozen. Should a nest be found later on in the season, when the mother has been long dead and the leaves have become dry and discoloured, the whole series of cells can be lifted out as though they were a long thin cigar.

As a matter of fact, these nests are frequently found, for the leaf-cutter bees are fond of using tunnels in the old timber of sheds, outhouses and such like. There is one question that is inevitably associated with the finding of one of these nests : how does the bee in the first cell—surely the one to come to maturity first—get out of its cell when there is a whole row of brothers and sisters in front of it who will be progressively slower in developing? I have already mentioned that in bees the males usually appear on the wing before their females. For this to be possible amongst the leaf-cutters it is obvious that the first-laid eggs, those in the cells furthest from the entrance, must give rise to females, while those in the cells last completed are going to become males. Exactly what makes the males come out in proper order, and after them the females, is not known. Nevertheless, it is probable that the cell nearest the entrance is the one to be affected first by climatic and atmospheric

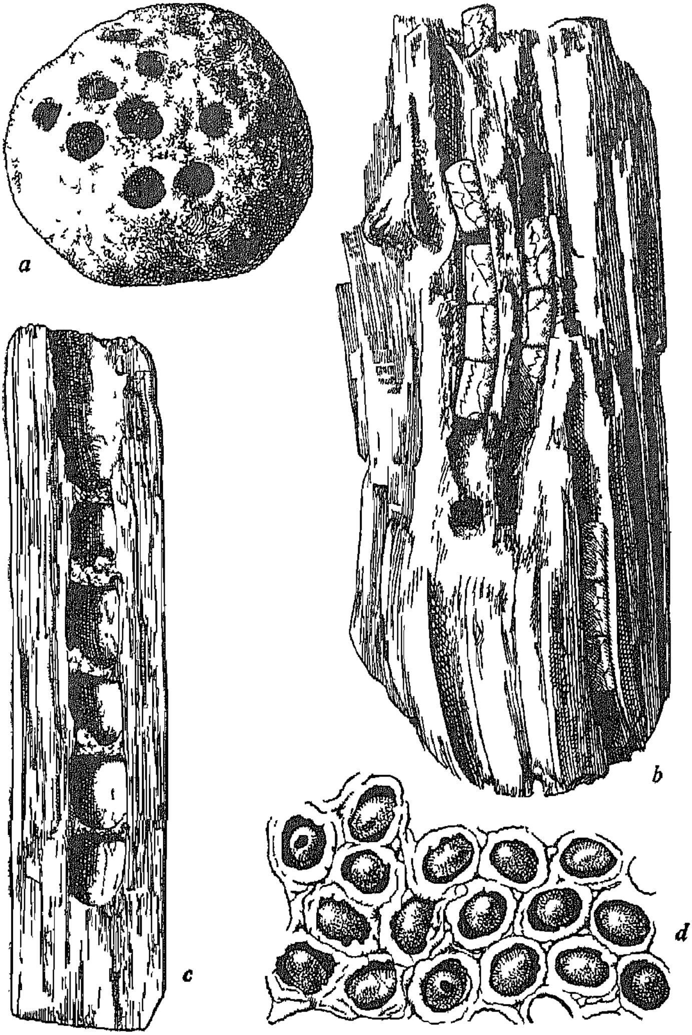


Fig 6

Nests of solitary bees; *a*, the mason bee, *Chalcidoma muraria*; *b*, cells of leaf-cutter bee, *Megachile willoughbiella*; *c*, cells of carpenter bee separated by paste of wood fragments; *d*, *Osmia rufa*, showing cocoons in clay cells

changes, and once its inmate has bitten his way first through the tough cocoon and then the plug of leaves, the cell next in the series will be exposed to the same conditions as those which induced the previous emergence.

On the whole it seems that the habits of the leaf-cutter bees are more uniform than those of *Osmia*. This, at any rate, is true of the species whose ways we have had a chance of studying. The bees themselves, if they are considered as they occur over the whole of their range, show much diversity of colour and form, though they all have, of course, the essential features that make them members of one large genus—*Megachile*.

Quite close to them in the matter of classification are Fabre's mason bees. They are, in fact, called *Chalcidoma* and not *Megachile*, largely on the strength of having different habits. They build up, you remember, an elaborate nest of cemented earth particles and have no use for materials obtained from plants. Because of this they are sharply distinct from the leaf-cutters. But, as so often happens when we attempt to classify insects according to their habits, the distinctions frequently break down. There is a bee called *Chalcidoma lefebvrei* which uses materials of both plant and mineral origin in the construction of its nest. And it uses them so elaborately and with such remarkable skill that I propose to borrow once again from the works of Charles Ferton and give a short account of how this bee makes its nest.

Ferton watched it in Algeria, the country of so many interesting bees and wasps. It selects, as a nesting-place, small cavities in rocks that are lying about. Each cell is built up out of a fine grained cement that the female makes by mixing dust with saliva. As soon as one cell has been finished, provisioned and has received its egg, another is built in contact with it until the little cavity is filled. Altogether between two and four cells are made and so far the bee has not displayed anything unusual in her technique. But on the completion of the last cell that fills up the cavity there is still a small hollow on the rock marking the place where the nest has been built. It is the way in which *Chalcidoma lefebvrei* fills this little pocket that places her in the front rank of bee architects. She first of all manufactures a fine vegetable paste by chewing up a piece of leaf and mixing it with saliva. It is carried home as a small lump of greenish putty and there carefully spread over one spot on the exposed surface of the nest. The bee then goes off again and this time returns with a pebble which may be as large as her head. Pushing it first one way and then another, she finally presses it down on to the prepared bed of vegetable cement. After this another bed of cement is prepared and again a suitable pebble is pressed onto it. And so on until the surface is covered with a layer of fine fragments of stone. If the bee is not satisfied with a single layer, she adds another and sometimes even a third until the actual site of her nest is marked by a low dome.

One nest that Ferton examined was finished in twenty-four hours. He found that the vegetable cement had set so hard in this time that he had to use a pair of tweezers with considerable force in order to break into the nest. Another nest contained forty-seven little pebbles, which together weighed 288 centigrammes or roughly one ounce.

By introducing *Chalcidoma lefebvrei* I have given myself an excuse for making a digression. I propose to make a comparison between this bee and a solitary wasp that has acquired a certain fame on account of one particular aspect of its habits.

The wasp is called *Ammophila sabulosa* and is decidedly elegant in appearance. It is extremely slender in build, black with a red tip to its tail and with a long thread-like waist between the abdomen and thorax. This graceful insect is a lover of the drier parts of the country and is found quite commonly on the sandy heaths of Southern England. To provide food for her progeny, the female hunts caterpillars which she overpowers and reduces to a state of paralysis with a thrust of her sting. The helpless caterpillar is then dragged home to a previously-prepared burrow where the wasp lays an egg upon it.

So far there is no obvious resemblance between the habits of the wasp and the bee. The similarities you may have noticed, such as the preparation of a burrow and the foraging of food with which to stock it, are common to the general run of solitary bees and wasps.

It is the final stage of her work that makes *Ammophila* somewhat exceptional among wasps of her kind, and her behaviour now is regarded as useful evidence whenever there is a discussion on the subject of intelligence among insects. Having completed the internal arrangements of her single-celled nest, she then actively fills in the mouth of the burrow with sand, using her front feet as though they were a pair of brushes. But this is not enough; she must then go off and bring back a small pebble with which she appears to ram down the sand more firmly.

Some students of insect behaviour have fancied they see in this particular aspect of the wasp's behaviour a glimmer of intelligence, because before she uses the pebble as a ramming tool she must have been aware, first, that the sand needed ramming, and second, that a pebble would be the tool to do it with.

But there may be an alternative explanation. It is possible that what passes for an act of ramming is no more than an attempt, on the part of the wasp, to wedge the pebble firmly into the mouth of the burrow and hardly different in meaning from the pushing and shoving that *Chalcidoma* gives to her pebbles before she is satisfied that they are firmly sitting on their bed of cement. This interpretation may, of course, be wrong. Nevertheless, I find it hard to see more than a difference in degree in the wasp's and the bee's use of pebbles in the final stages of nest-making.

All this is by the way, however, for in this book I am trying to restrict myself to making plain statements of fact.

Turning back now from the path of pleasant, but, unfortunately, often unprofitable theorizing, we will take a look at the last of the solitary bees whose habits need to be considered.

This bee is *Anthidium manicatum* and earlier on I referred to the female's habit of using vegetable fibre for making her nest.

The female is one of those that collect pollen on the underside of the abdomen. She, together with her mate—a heavily-built insect, black richly marked with yellow—has a fondness for the flowers of the Dead nettles. When the time comes for her to make a nest, she appropriates any empty burrow or tunnel-like cavity in woodwork and tree-stumps. The vegetable fibre with which she makes her cells looks just like cotton wool and consists of the fine down that thickly covers the stems and under-surface of the leaves of certain plants. The bee scrapes off the fluffy material with her jaws and when she has rolled up a sizeable ball flies off with it to her nest.

Should you, while dismantling woodwork or breaking up old timber, come across one of these nests, it will look like a short length of very thick woollen cord. The cells fit close one against the other, like those of the leaf-cutter bees, and in each of them lies a tough brown cocoon from which the bees will emerge round about midsummer.

Chapter Nine

THE SOCIAL BEES: *APIS*, THE HONEY-BEE

ALTHOUGH the solitary bees far outnumber the social species and have nest-building habits that, in my opinion, surpass those of their social relatives, they are much less well known. For one thing it is always a question of the habits of a single insect. She is shy in the extreme, unobtrusive and at the slightest disturbance to her work is likely to lose heart and desert the home she has begun to make. Very few of us possess enough perseverance to track down the solitary bees to their nesting places, and how many of us have a Ferton's skill in recording and interpreting the observations we might make should we be lucky enough to find a particular species at work?

But how different a story when you leave the solitary bees and go to the social bees. Here, you feel, life goes at a faster pace. The elusiveness of the solitary mother, pitting her strength against an army of hostile forces and hurrying, unaided, through her complicated programme, gives way to the bustling aggressiveness of the teeming virgin state. And there is this one big difference between the two kinds of bees. The units of the social colony, the sterile daughters of a queen mother, are tied to the site of their home by a much stronger bond than that which holds the solitary female to her nest. No matter how much you disturb them, nothing will induce a colony of bumble-bees to desert their nest. Nor will the honey-bee, though often violently handled and tormented to the point of having its social organization completely disrupted, decide out of sheer despair to abandon its home. It is the same with the social wasps that every few years plague us with an abundant increase. They can be attacked with fire and water. Their underground nest can be besieged with fork and spade and dug out, smashed and in fragments, from its hole. But the wasps that escape the attack will continue to seek their home where they have always found it, huddling together perhaps on a piece of broken and useless comb until rain, starvation and listlessness combine to destroy them.

The workers of the social colony, be it of wasp, bee, or ant, are unable to live an independent existence. Separated from their fellows they quickly succumb to a paralysing inertia. Their behaviour ceases to have either direction or purpose, for attachment to the home and its site is so much a part of the whole behaviour pattern of the insect that, once the link is broken, the impulses and urges to normal activities can no longer arise.

As I shall show later, the queen honey-bee is physically unable to live for long without her workers. In a sense she has become parasitic on her own children. Possibly it is the same with the queens of the Stingless bees, but unfortunately very little is known about them. The queen bumblebee is nearer in her behaviour to the female solitary bee; her attachment to her nest becomes firmer with the passage of time. In the early days of nest-building she will readily desert her home if disturbed; but later on, when the time approaches for the emergence of her first brood of workers, she becomes increasingly fond of her family and cannot be turned away from them. Perhaps, indeed, there could be no going back. The vast expenditure of energy could not be replaced for the same purpose; and the machine is too worn out to perform again a long and complicated series of labours. The queen bumble-bee needs to hold on to the nascent family she has created.

Before we look more closely into the life of the bumble-bee, let us see what goes on within the colony of the better-known honey-bee. The swarm is a good starting point; in flight or clustered in a dense mass on the branch of a tree, it is impressive and even a little frightening to those who are not familiar with the ways of honey-bees.

The swarm is the beginning of a new colony of bees. It may contain as many as twenty thousand bees, but the number is more likely to be somewhere between twelve and fifteen thousand. Yet in spite of all these bees, the future of the swarm, indeed its very existence as a community, is vested in a single individual—the queen. Without her it lacks social cohesion and the bees are doomed unless they are able to return to the hive whence they came and find there another queen to whom they can give their allegiance. Nevertheless it seldom happens that misfortune overtakes the queen of a swarm, for she is well guarded by the huge force of armed workers that accompanies her.

The first thing that the swarm must do is to get under cover as soon as possible. Wind, rain and cold are its greatest enemies. There is no delay, for a certain number of bees at once leave the swarm and go in search of permanent quarters. If the scouting bees discover a home to their liking they inform their sisters and the bees move off, perhaps to occupy a vacant hive, but more often to settle down in a chimney or a hollow tree.

As far as I know, no one has offered a satisfactory explanation of how the first scout, once it has developed a liking for some particular cavity, conveys its choice to its fellows. To see a large swarm of bees loosen from their clustering place in preparation for the next stage of their journey is an exhilarating experience. The bees, which hitherto have clung almost motionless to each other, are suddenly caught up by a wave of excitement. All is seething motion as they launch themselves into the air. At first their flight seems quite aimless. Gradually there is a movement in a particular direction, the bees close their ranks, the swarm becomes denser and after a minute or two whirls off like a cloud of smoke carried by the wind.

Once installed in their hollow tree, the bees form another cluster and begin to secrete the wax with which to build their combs. They can do this thanks to the full crop of honey with which they left home. I am inclined to think that they just cannot help secreting this wax. It is not that they feel an urge to build combs quickly so that the queen may have somewhere to lay her eggs. Unless the honey carried by the bee is emptied into the honey cells as stored food or used as fuel to keep it functioning efficiently, a certain amount of it is automatically diverted to the wax-making factory. This is beneficial to the bees of a swarm because they find building material to hand just when they most need it.

As fast as the cells are built the queen lays an egg in them, though certain areas of the growing combs are always reserved for the storage of nectar and pollen. The workers go about their tasks with an output of energy at the highest level. Or so it has always seemed to the beekeeper, who, it must be admitted, often sees his bees with more indulgence than discernment. But we take the bees' enthusiasm for work for granted. It brings a steady flow of nectar and pollen into the waxen nest so that a few weeks later a new generation of bees has made its appearance, ready to take over the care of the colony and fill the places of their sisters, by now old and worn out from their labours, and dying in ever-increasing numbers.

With the coming of winter the work of the bees gradually

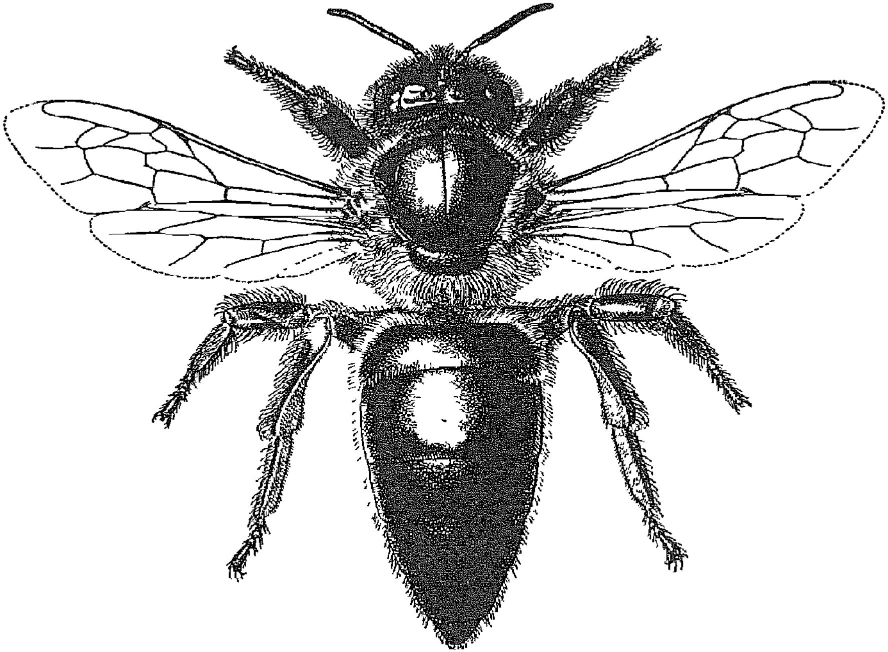


Fig. 7
The queen honey-bee, *Apis mellifera*

slackens. As the weather gets chillier, they draw closer and closer together for warmth until they form a tight cluster. But the honey-bee does not hibernate. In the centre of its winter cluster there is warmth and movement so long as the bees have honey within easy reach. The honey is vitally important. By eating it slowly the bees acquire the energy to maintain a temperature that is constant and much higher than that of the cold winter air outside. Unless the honey-bee had formed the habit of storing nectar far in excess of its immediate needs, it would have no means of surviving the long winters of our northern climate.

The ways of the bumble-bees are very different. Their queens spend the winter in a death-like sleep, hidden away in the ground or some equally safe hiding-place. All the reserves of food that the queen bumble-bee needs to keep her alive are stored as fatty tissue in her own body.

As soon as the spring comes the honey-bees begin to fly from their hives. They find the earliest flowers and rifle them of their pollen, and when the fruit trees begin to bloom they gather nectar to replenish their rapidly-dwindling stores of honey. And all the time the number of bees in the colony rises until there seems to be no end of them on the densely-crowded combs.

With the increase in the size of her family the queen mother grows in fertility. She becomes the perfect egg-laying machine. Except for an occasional pause to rest or take food from one of the small retinue of workers always ready to proffer it to her, the queen wanders from comb to comb in her endless search for empty cells. She used to be credited with the ability to lay 5000 eggs a day at the height of her reproductive powers. But considering that she has to lay each egg in a separate cell which she must also find for herself, an output of this size would indeed be a remarkable feat for even so prolific and tireless a creature as the queen honey-bee. Modern observers tell us that she rarely lays more than 1500 eggs a day.

Beekeepers, since they more than any other body of people have a special interest in the matter, have very decided opinions about the aim or purpose of the honey-bee's ceaseless quest for pollen and nectar. Many of them consider that it has no other object than to provide the colony with a store of food with which it can replace annually its population of workers and tide itself over periods of dearth. The colony is looked upon as permanent, and its annual burst of energy serves only to prolong its existence as a self-contained sterile organism. This is a curious point of view. It proceeds, I think, from the wish that the honey-bee ought to behave in a manner most convenient to the beekeeper, making plenty of honey and never indulging in hazardous swarming adventures.

Bee-breeding, by scientific methods, aims at producing bees that will in fact behave in this ideal way. I am not concerned with such ideal bees at the moment. It is the honey-bee that has existed countless ages whose habits I am trying to describe. It is not a domestic animal in the sense that domestication means, among other things, dependence on the care of man, for the honey-bee is as happy living in a hollow tree or the roof of a building as in a modern hive. For vigorous bees of this kind the gathering of nectar is a means and not an end. I am not saying that the bees are conscious of any particular purpose as they forage for food among the flowers, but when food is plentiful and prosperity comes to the colony, the activities of the bees are directed towards reproduction. Like all organisms, the honey-bee obeys the universal law that it must reproduce itself or die out. Certainly it has evolved a novel and rather precarious way of doing this. At least so it seems to us. If, however, we take into account that the honey-bee is a native of warmer countries than ours where swarms can issue from the nest without being at the mercy of a fickle climate, the method makes more sense.

The honey-bee's reproductive arrangements are marked by an absence of urgency. There is a lack of whole-heartedness about the affair that has made people wonder whether swarming is after all an essential part of the bee's life history. As kept in hives, bees do not swarm every year. The queen bee lives for three or four years, and if the season in any one of them is not propitious for the great adventure, why then reproduction can be postponed. I hasten to add here that by reproduction I do not mean the begetting of sterile workers, but of males and perfect females that can mate together and become the parents of other colonies so that where there was one colony there now exists three or four that have been budded off from it. Unless this regularly happened in a state of nature, disease and accident would long ago have combined to wipe out the honey-bee.

Having started with a swarm we cannot do better than end with one. The life cycle of the bee will then have been completed.

If, as very rarely happens, a hive has been left quite alone and the space occupied by the bees has not been increased by the addition of extra combs, the bees soon may become uncomfortably crowded. Every cell is filled either with honey or pollen, or with growing bees. The workers are faced with a critical shortage of space; it is impossible for them to continue doing quite the same things as have occupied them so fully for many weeks. If the crisis is to be met a new direction must be given to their energies. This is indeed what happens. The behaviour of the bees is set upon another course. The impulse to swarm has pervaded them and released them for a time from the restless urge to go out and forage for food. A subtle change comes over them; they hang from the combs in dense festoons. The bustle of early days has died down and in its place there is a kind of languid expectancy.

As new bees emerge from their cells, these empty cells are no longer filled immediately with eggs by the queen, for she, too, is affected by the changed mood of the bees. The workers are reluctant to ply her so freely with the rich food that stimulates a heavy flow of eggs. Her abdomen, distended and swollen with its burden of ripening eggs during the preceding weeks, now begins to shrink. The queen becomes slim again and almost as nimble as she was in her virgin days.

Swarming is the most exciting phase in the life of the honey-bee. Exactly what causes it no one knows, though there are very few people experienced in bees who are not ready to come forward with some explanation. There is the school of thought that maintains that bees swarm to escape from the attentions of the over-zealous beekeeper; these are the swarms of despair. Another class of beekeepers, fortunately not numerous, regards the whole thing as most unnatural, and if the bees adopt this extreme course of action then they must be suffering from some disease or other. But theories apart, there is not a beekeeper alive who is immune to the thrill that belongs to the swarming of bees.

I can no more put my finger on the trigger that sets in motion the preparations for swarming than I can say what brings a pair of sparrows together in the spring. The love-making of birds and the swarming of bees are just part of a scheme that provides for further generations of sparrows and bees to take the place of those that must eventually die.

But to get back to the bees crowded upon their combs and waiting for the moment to arrive when they will be filled with an almost crazy impulse to rush from the hive and fly into the air. At this time the large thimble-shaped queen cells are found suspended from different parts of the comb. They hang downwards with the opening beneath, unlike the horizontal cells that make up the structure of the comb itself. In each of these waxen queen cells is a grub, lying, or rather wallowing, in a bed of creamy paste called royal jelly.

There is much disagreement among beekeepers as to how the egg that produces each of these grubs got into the royal cell. Those who measure the behaviour of bees by the same standards as they measure the conduct of their fellow-men will not have it at any price that the queen herself could have laid them there. How unlikely they say that she would take this foolish step that must inevitably lead to her dethronement, or, even worse, to her death! For the young queens to which her eggs give rise are a murderous brood, who would not hesitate to kill their mother if they got the chance.

All this is a very sensible line of reasoning if bees could reason as clearly as beekeepers. But we should not let admiration and gratitude for many services rendered beguile us into crediting the honey-bee with a foresight she does not possess. There is really no need to speak of dethronement, for the queen is no ruler. The rivalries of royal succession mean nothing to her; nor is she troubled by the thought that one day she will be rejected by her workers in favour of a young and vigorous daughter. The risk the queen appears to run in laying eggs in the special cells is all part of an elaborate mechanism designed for the formation of new colonies.

The grubs that hatch from these eggs are, as I said earlier, fed on a substance called royal jelly. It is secreted from glands in the worker bee's head and is highly nutritious.

The grubs receive an abundant supply of this food, so much, in fact, that they pass their larval period half submerged in it.

It is especially at this stage in the life cycle of the honey-bee that we feel the sudden impact of one of the most remarkable things about the biology of this surprising insect. The egg that is to produce the queen is identical with that which develops into a worker. That the same kind of egg can develop into either of these females depends on the kind of food that the growing larva or grub receives from the workers. If it is fed on royal jelly only it becomes a queen; if its diet is changed after the first three days and pollen and honey are added then the larva grows into a worker.

There is a world of difference between a queen and a worker. They are unlike in appearance, though this might not be obvious to the unpractised eye. The queen is larger and her abdomen is longer and more tapering; her tongue is shorter and she has no basket on her hind leg for collecting pollen. She is timid, forbearing to use her sting except on another queen, while the worker is courageous and ready to attack any kind of enemy. The life span of the queen may extend over several years, whereas the worker seldom lives in full activity for more than a few weeks.

Without workers to tend and feed her, the queen is helpless. Because of her complete dependence upon her workers she is—I hesitate to use the word in speaking of an insect held in such high esteem—degenerate. Nevertheless, she fulfils to perfection her sole function of maintaining the cohesion of the honey-bee state by laying a steady stream of eggs.

Park, an American entomologist and writer on bees, has expressed the view that it is not the queen that becomes the monstrous product of special feeding, but the worker.

Every fertilized egg, he says, is a potential queen, and it is through failing to give the grubs in the ordinary horizontal cells of the comb a constant and plentiful supply of food that the bees force them to develop into workers. The grubs undergo a kind of nutritional castration that makes them develop into undersized females—aggressive, acquisitive and endowed with an enormous capacity for work.

While the workers are lavishly feeding the grubs destined to become queens, the queen mother is becoming more and more restless. I have already said how, at this critical time, her abdomen shrinks in size, leaving her lighter and more mobile, so that she moves across a comb as swiftly as a worker. This is an essential part of the plan, and we can easily see the value of it. For if the queen is to fly with the swarm her weight needs to be reduced so that her wings, idle for many months now, will be able to lift her.

Do the bees deliberately prepare the queen for this momentous flight by starving her or is there some other, more plausible, explanation? If you choose to regard the honey-bee as a creature of instinct, behind whose manifold activities there is no glimmer of intelligence, then you will try to find in the changed conditions now controlling the colony some factor to which the gradual shrinking in size of the queen's abdomen is simply an automatic response. Such a mood is unromantic, but it may lead nearer to the truth than mere sentimental speculation.

About nine days after she has laid the first of these eggs destined to become queens the old queen leaves the hive with a swarm should the weather be fine enough. A week later the first of her royal daughters will have emerged from her cell and be running free in the colony. Her mother, you will note, has left with a wide margin of safety.

It used to be thought that the majority of bees that accompanied the queen were old bees. It is known now that most of them are young—at an age when they are best able to serve the needs of the colony by producing wax for building the new home and elaborating the brood food on which a new generation of workers is to be raised.

At home within the parent colony the swarming fever has not abated. As soon as the first virgin emerges, the bees swarm with her. The same happens with others that emerge later, though owing to the dwindling number of bees the swarms become progressively smaller. At last a stage is reached when the depopulated colony must conserve its waning strength or run the risk of self-annihilation. Once more there is a reorientation of energy. The bees are now bent on holding together what is left of their colony.

There are still virgin queens waiting to leave their cells. Impatient, one of them at last bites her way out. Her impulse is not to leave the hive, for the bees no longer have the urge to embark on another colonizing adventure. She seeks out instead the cells that still contain royal sisters approaching the completion of their development. Her purpose is sinister. The cells are bitten open by the workers, aided perhaps by the excited virgin. One by one the young queens are destroyed whatever their stage of development. Those that have sloughed the pupal skin and become fully adult are probably stung by the virgin as they lie in their cells. But the pupae, less advanced and still soft and white, are chewed to pieces, their harder parts being carried away and their juices swallowed by the workers themselves. The victorious queen, her rivals disposed of, now takes her marriage flight in all safety and finally becomes the queen mother of the colony.

It is a fact that queens, especially young unmated ones, cannot abide one another and will always fight when they meet.

Their combats have often been described, freely embel-

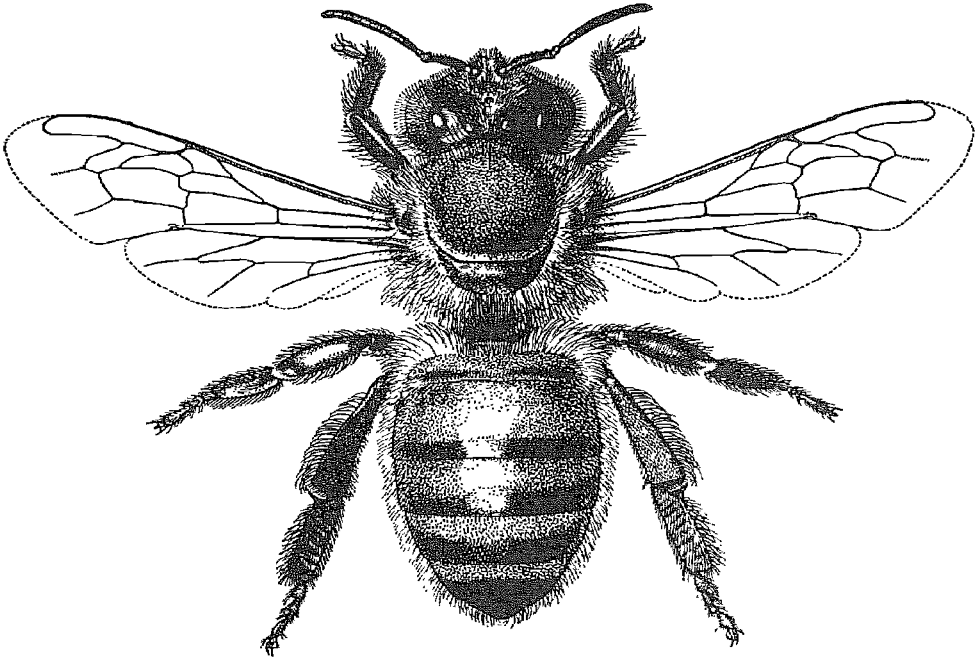


Fig. 8
The worker honey-bee, *Apis mellifera*

lished, more often than not, by imagination. Perhaps observers have been disturbed at the sight of members of royalty engaged in hand-to-hand combat and have tried to give the conflict a dignity befitting its royal protagonists. I have seen these fights many a time. They are no less ugly than any fight in which the dominant urge is to reduce a rival to immobility.

There is no sparring when the queens meet; they do not thrust and parry like a couple of well-matched duellists, or watch for the chance to deliver a fatal blow. Just a sudden coming-to-grips and locking together, with each queen trying to seize the other with her mandibles wherever she can. Often it is the wing or a leg that is grasped. Thus anchored, one queen has the better advantage. Holding on grimly, she feels around with the tip of her long flexible abdomen until at last the curved sting finds a chink in the armour of her enemy. The unlucky queen dies quickly and her corpse is cast out by the workers just as they remove any bit of rubbish that soils the cleanliness of their home.

As soon as the wave of regicide has passed and the mated queen settles down to a long period of peaceful egg-laying, another little matter occupies the attention of the workers. The males or drones are still with them, draining the food resources of the colony. There is nothing they can now usefully do and their disposal is clearly in the best interests of the community. Their passing is usually referred to as the slaughter of the drones, but it lacks all such elements of sudden drama. The workers refuse to feed their helpless brothers, or chivvy them from the open honey-cells where they might get their own refreshment. Slowly, but with a kind of blind determination, they drag them, one by one, exhausted from the hive, biting at their wings or seizing them by a leg, but never, as far as I am aware, stinging them. At this time, and after so much maltreatment, the unfortunate drones are too feeble, too listless, to excite their grimly efficient sisters to the point of using their stings.

This casting out of the drones can easily be seen at the hive entrances towards the end of summer. The hive entrance is, in fact, the scene of many interesting activities of the bees; it is here, for one thing, that they can often be seen fanning their wings. They will do this to reduce the temperature of the hive in very hot weather should it rise above that to which they are normally accustomed. Their fanning is also connected with the storing of honey. If, for instance, the weather has been fine and warm and flowers have been secreting nectar freely, the bees will have been very active and stored much nectar in their combs. This nectar, however, contains an excess of water that must be got rid of before the bees will seal it over, as honey, in the cells. Within the warm hive a great deal of moisture evaporates from this unripe honey, and the bees, by fanning their wings at the entrance, cause it to pass out with air currents. On warm, still evenings, after there has been what beekeepers call a honey-flow, the sound of the fanning bees is one of the most noticeable things in an apiary.

Another interesting activity of bees at the hive entrance is the behaviour of those that appear to be doing a kind of guard duty, challenging incoming foragers and holding up unwelcome intruders such as wasps.

The posting of guards is not peculiar to honey-bees; it happens regularly with wasps and hornets, but does not seem to be a constant feature of their organizations. This, at any rate, is my experience of the social wasps that occur in this country. Some days a hornet will be stationed at the entrance to the tunnel leading to the nest, but at other times there is no sign of a guard. On the arrival of another hornet the sentry will fly up at it when it is within about eight inches of the entrance and the two of them will frequently tumble down together. This will often cause the incoming forager, if heavily loaded with booty, to take a little rest before making a second attempt to enter the tunnel.

When a hive of bees is disturbed, a large number of workers crowd about the entrance and make it impossible for an intruder to enter. But during spells of peaceful activity guards are not always on view. I cannot help thinking that their appearance is always a response to some previous threat. If bees from other colonies attempt to rob a hive, the inmates form a dense throng at the entrance, waiting to meet them. Frequently they stand with their front legs slightly raised in an attitude of alert. The hornet and the wasp do the same, though they tend to fly up at any moving object that comes within range of their vision, whereas the honey-bee, I have noticed, waits until it actually makes contact with its enemy.

Chapter Ten

THE SOCIAL BEES (CONT.): THE BUMBLE-BEE

OUR feelings towards the honey-bee, *Apis*, are decidedly mixed. Her industry is admirable, of course, though she is no more hard-working than any other kind of bee. We think highly of her, I believe, solely because she benefits us personally. And then there is that object of wonder, the bee society itself—a perfect example of smooth co-operative effort in which there is no conflict of wills because there is no clash of wishes, an organization as worthy of our earnest attention as anything the insect world has to offer.

What does rather spoil things is the uncertain temper of the bees themselves. How difficult not to feel resentful when, without apparent provocation, a bee comes at you with the speed of a bullet and drives home her fiery sting! Your attitude becomes particularly confused when this happens after you have been invited by a friend to inspect a hive of bees and have come, with courage held in both hands, duly to pay homage.

Is there this ambiguity in the way we feel about the big, homely bumble-bees? Their societies may be crude and ill-organized compared with the neatly dovetailed efforts of *Apis*, but the bees themselves never fail to inspire feelings of warm affection. For one thing, a bumble-bee is a pleasant creature to look at. Some species, such as *Bombus lapidarius*, with its velvety black fur coat and red tail, or *Bombus* *lucorum*, with a white tail and rich yellow bands on a black coat, are really most handsome insects.

Whereas there are only three different kinds of *Apis*, or honey-bees, known in the world, there are around three hundred different species of bumble-bees. They are at home in the cooler parts of the world, being found all over the Northern hemisphere. The vast regions of temperate Asia are full of them, and some of the finest of all are native to the mountains of Tibet and Northern India. Great Britain has some twenty different species, some of them so much alike that it takes a sharp eye and keener interest to tell one from another.

With regard to the communal life of *Apis* and *Bombus*, there is really very little resemblance. In each kind of society, however, there is this fundamental element in common: the colony consists of a variable number of sterile females or workers and a single queen who is their mother.

The bumble-bees construct no edifice of comb to house their brood, and they rarely store more honey than they need for their immediate existence. Compared with the perennial life of the honey-bee colony, theirs seems an ephemeral existence.

Between the two queens there is, indeed, a world of difference. The honey-bee has no completely female individual to show you. The total number of feminine characteristics, such as we define them in a bee, are divided between queen and worker, so that each becomes the complement of the other with the wider range of function vested in the worker. In the queen bumble-bee all these functions are combined. Not only does she mate and lay fertilized eggs, but she can also do all the work necessary to bring them through to adult bees. In short, she has not forfeited her independence like the queen of *Apis* and needs no help when the time comes to found a family.

How the queen bumble-bee sets about home-making is a fascinating story, an epic of endurance beside which the murderous adventures of the virgin honey-bee seem narrow and trivial. Not that strife is lacking among the bumble-bee queens once they are launched upon the business of raising a family; but their combats have a different significance from those of *Apis*. They are part of a lively struggle for existence and are not, as in *Apis*, an essential element in the honey-bee's elaborate method of reproduction.

The young queens of *Bombus* pass the winter in hibernation, tucked away beneath moss or more often, perhaps, in a hole in the ground. When spring comes and warmer temperatures penetrate to their sleeping quarters, the queens are roused once more to activity. They spend a week or two doing nothing in particular, basking in the sunshine and feeding at whatever spring flowers happen to be in bloom. Sooner or later they abandon their carefree ways and begin to search for a place to build a nest.

The nesting habits of bumble-bees are by no means uniform, but we can take one of the commonest species and see how the queen sets to work. *Bombus terrestris* is an easy choice. She is black with dull yellowish brown bands and the tip of her abdomen is buff coloured. Throughout the spring the queens of this bee may often be seen quartering the ground in their search for a nesting site. Frequently a queen will settle, and disappear beneath a tuft of grass, or under fallen leaves. But after a casual inspection she flies up again and continues her search.

At last the queen alights at the mouth of a little hole, half hidden by wisps of grass or odds and ends of rubbish. It is almost certainly a deserted mouse burrow and at its end is the abandoned nest that is the object of all her patient searching. Here is the little heap of dead leaves and grass fragments, damp to be sure, that will later on help to conserve the warmth of the bumble-bee colony and keep it snug.

The queen pulls the material all into a neat pile, leaving in the centre a small hollow chamber in which she will rear her first brood of workers. The success of her enterprise depends on a constant supply of honey. Without it the queen soon becomes torpid, unable to produce by muscular movement either the warmth to keep her nest dry or the energy to care for a young family. Therefore one of her first tasks is to make a waxen honey-pot. Since she forages in all kinds of weather, there is not much difficulty in keeping the pot filled. Another waxen pot, or cell, though very much smaller, receives her first eggs, usually six to eight of them.

The bumble-bee grubs do not, like those of the honey-bee, live each in a separate cell. They are crowded together in a thin waxen bag. As they grow and threaten to burst the bag their mother patches it with more wax. The queen feeds her brood on a mixture of honey and pollen, thrusting her tongue through the gaps in the flimsy bag and forcing, or vomiting up, droplets of the liquid food required by the grubs.

When full grown each grub spins for itself a tough silken cocoon. The cocoons are spun within the original bag and form a compact mass of rather distinctive shape for the following reason: the queen incubates her brood in all stages of its development, pressing her body against the grubs so that her warmth will permeate them. When the cocoons are being spun, the pressure from the queen's body tends to push the spinning grubs outwards all the while, flattening their mass so that they come to be arranged roughly in three rows with the middle row lying lowest. The finished block of tough, hard cocoons thus acquires the shape of a saddle along which the queen lies, closely embracing her family with outspread legs and warming it with her body.

About four weeks elapse between the laying of the eggs and the emergence of the worker bees. At first they are pale in colour, very feeble and with a damp look about them. But within a couple of days or so the colour of their coat has deepened and brightened and the bees themselves, miniature replicas of their mother, are vigorous enough to play their parts as units of the colony. They lose no time in bringing in food and helping their mother to raise further contingents of workers.

The queen lays her second batch of eggs in a cell fixed at some point on the edge of the original block of cocoons. A third batch is laid on the opposite side. The bumble-bee nest therefore grows upwards and outwards and resembles very roughly an inverted cone. It has no special structure, no galleries or neat layers of cells. It is really nothing but an agglomeration of empty cocoons below with clumps of full cocoons above alternated with bags of larvae in various stages of growth. The vacated lower cocoons are used by the bees as additional storage space for honey. Their main supplies of honey, as well as the big stores of pollen, are kept in waxen pots built specially for the purpose.

The colonies of *Bombus terrestris* never become very populous though they often contain many more workers than the nests of most of the species of bumble-bees that occur in Great Britain. Between one hundred and one hundred and fifty is about the number found in prosperous colonies. This is very small indeed, of course, compared with the tens of thousands of workers found in the hives of the honey-bee.

The bumble-bee queen is a very hard-working insect. From dawn till dusk, and in wind and rain, she will not hesitate to fly in search of nectar and pollen. Having a much longer tongue than the honey-bee she is able to visit a wider range of plants and can usually get her supplies without going far for them. Her indifference to bad weather was brought home to me very forcibly on the morning following the disastrous day in 1949 when snow fell heavily at the end of April. A bumble-bee queen belonging to the species called *lucorum*, very like *terrestris* but with brighter yellow bands, kept settling on the snow that lay thick on a grassy bank in my garden. Her short flights were laboured, her movements slow and full of effort. She was becoming numbed with the cold, but in spite of her distress she kept flying up, circling around, and refused to leave the spot. I knew she was trying to find the entrance to her nest, but there was nothing I could do to help her. Regretfully I left her, hoping she would survive until the thaw came. But she was tough, my *lucorum* queen, and the next day I had the pleasure of seeing her disappear down a little hole in the bank. A few weeks later workers of the same species began to enter and leave the same hole, and by July, to judge from the busy traffic, the colony had become very prosperous.

It is towards the end of July that the colony of *Bombus terrestris*, the species whose habits I am describing, reaches the peak of its growth. There are now large numbers of males and young queens in the nest. The queens live together with their mother in perfect harmony. The fierce combats in which the virgin queens of the honey-bee so often engage are unknown among the bumble-bees. The whole process of reproduction is different. Bumble-bees do not swarm, and since the future of their race is vested, at least for a time, solely in the young queens, these do not need to add to the risks of life by fighting amongst themselves. They will have to surmount many dangers later on, as we have already seen.

When fully mature the males leave the nest for good. But the queens are reluctant to leave home straight away. They take short daily flights and this may continue for some time. They may even do a little foraging, but this, I think, we must regard as somewhat exceptional. They will have ample opportunities for this sort of activity when they settle down to the serious business of making a home.

Certainly the most important reason for the young queens' flights is to find a mate. Eventually they are successful. Once fertilization has taken place, the queens are physiologically ready to enter the next phase of their life cycle. They need to fall into the deep sleep called hibernation, and they do not now waste much time before seeking out their winter quarters.

Strange as it may seem, not very much is known about the kind of resting place the young bumble-bee queens choose for their winter sleep. Sladen, who studied British bumblebees as no one before or after him in Great Britain, thought that the queens preferred a spot with a northern exposure, the reason being that they would thereby escape the risk of being lured too soon from their winter retreat by a burst of spring weather that came too early.

Professor Plath, an American who has written a delightful and most instructive book on the ways of North American bumble-bees, thinks that Sladen may be mistaken, and that the four points of the compass have nothing to do with the young queen's selection of her winter retreat. He has discovered that for one species at least, *Bombus impatiens*, the actual site of the nest where they were born has an irresistible attraction for the young queens. Around one such deserted nest, Professor Plath dug up in October no less than thirty queens, each in a little cavity about two or three inches below the ground. At this depth the ground is often frozen solid, but thanks to the chemistry of the bumblebee's body it does not freeze to death. Older writers used to think that the queens burrowed deep expressly to avoid the rigours of winter, but Plath's experience shows that excessive cold does not harm them.

Apart from the young queen's selection of her hiding place, we are still very much in ignorance as to what initiates her impulse to hibernate at all. Since it happens while summer is still with us, it certainly cannot be a response to cold. Nor need the queen be troubled by a shortage of food, for at the time of entering the stage of quiescence there are plenty of flowers in bloom.

We have in this country a species of bumble-bee known as *Bombus pratorum.* The rather small, active queens are among the first bees to appear in the spring, and they lose no time in founding their colonies. At the beginning of June you may be sure of seeing the brightly-coloured males feeding at the raspberry blossoms. Their mates, a new generation of young queens, are about also, though you do not often see them. By the beginning of July they are all safely tucked away for their winter sleep. They have, indeed, gone into hibernation at almost the hottest time of the year, to be aroused some eight months later by a temperature many degrees lower.

We have followed the young queens as far as we can and left them to sleep through the long winter months. But what about the mother and the workers who toiled so hard to raise them? With the departure of these youthful females, each the potential foundress of a new family, the old colony has fulfilled the purpose of its existence. Their mother, the old queen, is exhausted and can live but a little while. Sometimes she may be found dead within the nest; sometimes she just disappears and then, perhaps, you may come across her, sitting idly on a flower head, too feeble even to sip the nectar within her reach. Perhaps she wanted to see if those frayed wings would lift her once more so that, delivered at last from the burden of obligatory behaviour, she might enjoy a little leisure before her failing strength deserted her. Such a queen as this never returns to the nest, and since she has run the full gamut of all bumble-bee activities, soon dies.

As for the few remaining workers, they also will die now that the fertility of their mother has been spent. With no brood to care for, the point and purpose of their existence have vanished. Where once was bustling movement, there is now only listlessness and a mere staying alive until the energies of the bees have finally petered out.

As for the nest, now just a mass of empty cocoons, with its remains of stale pollen, the cast pupal skins at the bottom of the cocoons, and the thin overlay of wax particles, it soon becomes the happy hunting ground of a host of scavenging insects. To certain beetles in particular the crumbling nest offers a most attractive residence. They lose no time in moving in to lay their eggs amongst the débris. Here the grubs will find all they need to make them grow up into beetles like their parents.

Comparing the life histories of *Bombus* and *Apis*, we are struck by one outstanding difference. Whereas the colony of the honey-bee is perennial, lasting from one year to another with a proportion of the workers surviving the winter in company with the queen, the life cycle of the bumble-bee is an annual one, terminating at the end of summer with the break-up of the colony and the hibernation of the young queens.

Most of the British bumble-bees make their nests underground, choosing for their home, as far as we know, the deserted nest of a mouse or vole. Just a few are different in habit. These are the brown carder-bees, rather small bumble-bees that like to nest on the surface of the ground at the roots of rough grass. They get their name from their habit of teasing or carding into fine shreds the dry blades of grass out of which they build up their nests. If a piece of rough ground is scythed in late summer, the little mounds in which the bees hide their nests are often exposed. The bees come fussing out and fly around in great excitement. The species you are most likely to come across in this way is *Bombus agrorum*, the commonest of our three carder-bees. In spite of the loud buzzing it sets up if its nest is disturbed, I have never known this bee to attack anyone. The harmless males are brown, too. They can nearly always be seen, along with several other bumble-bees, feeding at the flowers of lavender in July and August.

Chapter Eleven

THE SOCIAL BEES (CONTD.): BEES WITHOUT STINGS

THE Stingless bees are natives of the Tropics; South America teems with them, and they are found also in the Old World from Africa right through to Australia. To my regret I have never seen these bees in their native haunts, and what I know about them comes solely from reading accounts given by other people. Among those who have studied their habits, no one has made a larger or more comprehensive contribution to our knowledge of the Stingless bees than Herbert F. Schwarz, of the United States Museum of Natural History. He has collected together every scrap of information about the species of the New World and pieced together the story of their lives as far as it is known. Dr. Schwarz has also shown how important a part these bees have played in the social, cultural and economic life of the Indian peoples of Central and South America.

The following brief account of the Stingless bees is derived from Dr. Schwarz' monograph.

The Stingless bees, or *Meliponidae*, have always excited the imagination of beekeepers for the simple reason that they are, as their name suggests, without a sting. That is, without a sting worthy of the name, because in the interests of scientific accuracy it is proper to mention that a vestige of a sting, a mere useless rudiment, is sometimes present. What could be more delightful than to keep these bees in hives, to handle them with as much ease as though they were a swarm of harmless flies and finally to be able to remove their stores of honey without the risk of being cruelly stung! To the nervous beekeeper who has no wish to prove his mettle by enduring tight-lipped the pain of stings, this must seem like a wonderful dream. As a matter of fact it is only a dream, for the Stingless bees, even if they cannot give an honest-to-goodness sting, are not without other, and equally unpleasant, means of defence.

If their nests are disturbed the bees will fly at the intruder in hordes, crawling into his eyes and ears, tangling themselves in his hair and creeping through every gap and fold of his clothing, until, tormented beyond endurance, he hastily retreats. Because of their habit of burrowing into the hair of the head and the beard, the Brazilians call the Stingless bees 'hair twisters'. All the time the bees are crawling into any orifice they can find, or getting themselves thoroughly entangled in their victim's hair, they continue to give him little nips with their mandibles, greatly adding to his discomfort.

There is one group of Stingless bees in Brazil called *Oxytrigona* that have improved on the rather simple offensive tactics of the hair-twisters, and indulge in a kind of chemical warfare. These bees place on the flesh of their enemy droplets of a caustic fluid that burn like fire and cause the most intense discomfort. No one seems quite to know from which end of the bee's body the fluid comes. Some entomologists think it may be secreted from an anal gland and that it finds a parallel in the fine spray of formic acid squirted up from thousands of Wood ants, *Formica rufa*, when their mound nests are broken into. Others think it is vomited up from the mouth at the time the bee is inflicting her bite. In support of the latter theory there are instances on record where Stingless bees have been known to put enemies such as wasps out of action by daubing them with a sticky liquid. Whatever the origin of their 'fire', as their defensive fluid is called, the fact remains that *Oxytrigona* can defend itself just as effectively as the honey-bee with its sting.

In talking about bumble-bees, I pointed out that aggressiveness varied from species to species; it is the same with the Stingless bees. Some have the reputation of being so gentle that they are known locally as 'little angels'.

The Stingless bees are all social in habits, living in colonies that contain workers and a fertile queen. At certain times of the year males are also found in the nests. There are so many different kinds of these bees and they show such variation in their nesting arrangements that striking a middle path in attempting to describe the habits that are common to all of them becomes almost impossible. Their communities are sometimes small, sometimes large. Some species may never produce more than a few dozen workers, while others, it has been estimated, may develop a population of 60,000. And as for their nesting sites, there are species that habitually nest in hollow trees, others that build underground, and others again for whom any odd cavity makes a suitable home. Perhaps no stranger nesting site could ever have been picked on by Stingless bees than two human skulls that were once found to house colonies of them. As a flight hole the bees chose one of the sockets of the eye.

And what of the actual nest of the Stingless bees and its architecture? How does it compare with the waxen combs of the honey-bee? Here it is possible to make a general statement that fairly well covers all cases. The combs lack the geometrical regularity of those made by *Apis*, and they are usually placed horizontally one above the other. Quite often the combs are enclosed in an envelope or involucrum that is largely composed of wax. The entrance to the nest is sometimes prolonged in the form of a spout or trumpet, made of some resinous material.

The honey-bee and the bumble-bees feed their young, as we already know, progressively, giving them food only when they are hungry. The Stingless bees, on the other hand, adopt a method known as mass provisioning, which is a feature of the solitary bee's way of caring for its young. Each cell is provisioned with the full amount of food required by the larva, and after the queen has laid an egg in it, is sealed over; it receives no more attention until its inmate emerges as an adult bee.

The Stingless bees are not different from others in the choice of their food; they need both nectar and pollen. The honey-bee stores both these substances, as we know, in the hexagonal cells of its comb. The Stingless bees adopt a different arrangement; they do not use the cells of the combs but keep their food, instead, in large waxen jars built specially for the purpose.

Now that we have some idea of the structure of the nest and know how the bees provision the larval cells and store their food, we may go a step further and see how life goes on with the colony. Are we going to find a similarity to the social organization of the honey-bee or do the Stingless bees perhaps resemble more closely the bumble-bees in their domestic arrangements?

Although Schwarz has tapped almost every source of information he could find, he is still not able to give us the full story. What is known about the details of social behaviour displayed by the Stingless bees is based on information supplied and published by many observers. These accounts do not always dovetail neatly into one another, and for the simple reason, I think, that observers have been studying different species of bees. Even though we should expect the broad outlines of their life cycle to be the same for all species, we must be prepared for plenty of variation in matters of detail. After all, have we not seen from the painstaking observations of Ferton how the bees of the genus *Osmia*, all very much alike in external appearance, construct nests of the most varied designs?

The queen of the Stingless bees is something of a mystery. No Maeterlinck has ever described her marriage flight. No one, in fact, seems to have any but the haziest notions about her nuptials. This need cause no surprise, suggests Schwarz, if we stop to consider that absolutely nothing was known about the mating flight of the queen honey-bee until the end of the eighteenth century, when the blind François Huber, assisted by the eyes of his faithful servant Burnens, revealed the truth about it. The honey-bee had been kept and exploited for centuries and yet the facts of its life history, so familiar to us nowadays, were obscured by misunderstandings and artless guesses. The Dutch naturalist Swammerdam, who made a careful investigation into its habits, was baffled by the whole business of fertilization, and put forward the quaint idea that the queen was made fertile not by an act of copulation but by an odour that came from the drone.

As for the queen of the Stingless bees, if nothing is certain about the way in which she finds her mate, she nevertheless comes finally to reign in a colony. She is the one and only queen mother—hers is the royal privilege of laying eggs. In this respect she resembles the queen honey-bee. But unlike that interesting and important female, she seems to entertain no feelings of violence towards her royal daughters, nor does she herself run the risk of falling a victim to their murderous impulses. The whole family lives in perfect harmony. Whatever the factors are that govern the process of reproduction, antagonism among the queens, so important in the social life of the honey-bee, is not one of them.

The impulse to fight among themselves is one of the most striking features of the behaviour of the young *Apis* queens, and it certainly plays a part in causing a swarm to leave the hive. The Stingless bees also form new colonies by a method of swarming, but what physiological condition in the parent colony precedes the issue of a swarm is not yet known. The swarms are often seen and apparently in all sorts of tropical weather. One species, *Trigona ruficrus*, will even, so it is recorded, send out a swarm in a thunderstorm. No day, of course, can be fine enough for the old queen of the honey-bee to leave with her swarm. Her daughters are less fussy, and though it is true that they will sometimes swarm in bad weather, I have never heard that they imitate their cousins of the tropics by choosing a thunderstorm for the event.

The Stingless bees are no answer to the modern bee-keeper's dream if only for the reason that their nest-building habits would make the use of a modern hive with its movable frames quite impossible. For another thing, these bees cannot withstand the cold of a northern climate. From time to time they have been brought to the continent of Europe and have survived for a few summer months. But the onset of cold weather has always been too much for them. They are essentially tropical bees and are active only within a range of fairly high temperatures. Here they are quite unlike the much more adaptable honey-bee, which manages to survive a northern winter and at the same time is quite at home in the tropics. According to Dr. Schwarz, it is now wild all over South America, having escaped by swarming from colonies taken there by Europeans. It has, in fact, become a rival of the Stingless bees whose colonies it is able to plunder and destroy.

About the honey of the Stingless bees, which excites in the first place the attention of the more powerful robber, *Apis*, I shall have something to say later.

Chapter Twelve

THE BEGINNING OF A SOCIETY

EARLIER I pointed out that the division of bees into social and solitary forms is made for the sake of convenience. When it comes to definition it is impossible to draw a sharp line of distinction between the two classes. For there are some solitary bees that show an advance towards a social type of behaviour in the sense that a number of females actually work together at a common nest. I have mentioned the small solitary bees of the genus *Halictus* many times. You can take them one by one and they show no deviation from the normal pattern of behaviour until you come to *Halictus malachurus*. This species looks much like all the rest, but in its habits it is decidedly exceptional. The females come out in spring, make their nests in the usual manner of solitary bees and die. Their labours give rise to a generation that comes out about midsummer. These bees are all females and they reproduce themselves by parthenogenesis. But this is not the important feature of *Halictus malachurus*. What is advanced in its behaviour is that these virgin females of the second generation nest in groups, sharing a common entrance and building together a single body of cells. They even go so far as to post a guard at the entrance of the burrow which says quite a lot for the co-operative effort that exists amongst them. The offspring of these females appear towards the end of summer and are of both sexes.

And then there is the case of *Allodape*, a genus of bees that occurs in Africa. Their habits dispose of the division of bees into social and solitary on the basis of whether they feed their young by the progressive method or by mass provisioning. I have already discussed in an earlier chapter what these methods of feeding mean.

The many kinds or species of *Allodape* are small bees, rarely more than half an inch in length and altogether insignificant in appearance. Yet their habits are truly remarkable. Dr. Hans Brauns, who lived in South Africa for many years, is responsible for what we know about these little black bees.

One striking thing about the ordinary solitary bee, as we have seen over and over again, is that the female makes a separate cell for each of her young. *Allodape* departs from a very general habit by dispensing with this feature of separateness. Her young share a common nursery and no kind of partition keeps them apart. Although it seems that all the species of *Allodape* are alike in their manner of housing their offspring, their methods of feeding them are by no means uniform. The commonest method is evidently this: having selected a suitable hollow stem, enlarged a bit in order to suit her requirements better, the bee lays an egg loosely at the end of the tube. Her egg is very large in proportion to her size. When the grub hatches, the mother gives it a lump of bee-bread which it clasps between two blunt outgrowths of its body. These outgrowths are called pseudopods, or false legs. Since the *Allodape* grub uses them for holding and not walking, they have more the function, I think, of a pair of hands. Later on more eggs are laid in the same nest gallery and finally the tube will be found stuffed with larvae or grubs in various stage of growth, each clasping its own lump of bee-bread. There may also be pupae present in the nest at the same time. All the while the mother keeps contact with her entire family. Furthermore she breaks all the rules by adopting the progressive feeding of the true social bees.

Chapter Thirteen

THE CUCKOO BUMBLE-BEE

The queen bumble-bee, as we already know, has to overcome many dangers before she has raised her first brood of workers and is well launched on the road towards full reproduction. But even then, when the little colony is firmly established, and the burden of foraging and looking after the home has passed over to the energetic workers, the labours of the queen may still be brought to naught. Should her nest be discovered by the cuckoo bumble-bee, she might as well have died in the frost of spring, for she will be able to make no contribution to the continuance of her race, though she will, of course, have done the unwanted visitor a very good turn.

The cuckoos that make life so difficult for the bumble-bees are so like them that you could not be blamed if you mistook one for the other. Nevertheless, there are certain differences in their structure that make all cuckoos different from the true bumble-bees. For this reason they bear the generic name *Psithyrus* instead of *Bombus.*

The female *Psithyrus* has lost the ability to make a nest and raise a family by her own unaided efforts. For one thing she is not equipped for foraging, as she has no pollen basket on the hind legs. On the other hand she has acquired, by way of compensation, other advantages that fit her for her existence—a particularly powerful sting and a horny integument that is unusually thick and tough. *Psithyrus* is well armed; she needs to be, for her path is not always smooth, and sometimes she achieves self-fulfilment only through strife and slaughter.

Like her host, the bumble-bee queen, *Psithyrus* passes the winter in hibernation. But she awakens from her sleep later. This is a convenient provision, for although she has a lot of searching to do it is an established bumble-bee colony that she is after and such is not available until some time in May at the earliest.

Things are easier for the cuckoo if the nest is not too populous at the time she finds it. She needs to ingratiate herself with the workers, for should there be a strong force of them they meet her advances with hostility. They may even attack and try to kill her, and in the skirmishes that follow the alien female will be overpowered and destroyed.

I once had a very prosperous nest of *Bombus terrestris* under observation in a box in a garden shed. This is the species, you will remember, that I used as a model in describing the life of the bumble-bee. For some reason the workers of this particular colony killed and threw out their queen. Here was a chance, I thought, to see how they would take to a cuckoo queen. Luckily I managed to catch one—*Psithyrus vestalis*, the species that regularly lives in the nests of *Bombus terrestris*.

I allowed my captive cuckoo to enter the box containing the queenless bumble-bees. The uproar was terrific, though I could not see what was happening because the actual nest was hidden beneath a thick layer of dried grass. This happened in the evening. By morning all was quiet. The workers had come to terms with the cuckoo, but at great cost of life, for all about the nest lay the corpses of no less than forty bumble-bees. I wondered how the cuckoo had fared and gently pulled away some of the nest material to see if she were still alive. She was, but I hardly recognized her. Almost her entire coat of hair had been rubbed off in the battles of the previous evening. And her tongue must have been seized and pulled till now it stuck out helplessly, a useless organ that could no longer be folded back, as all bees' tongues are, beneath the unfortunate cuckoo's head. Altogether she had been so badly mauled that she no longer looked like a bee but resembled instead some black-beetle that had found its way into the nest.

And yet, reduced as this valiant cuckoo-bee was to a state of extreme physical distress, she crawled feebly but with obvious interest over the comb. The workers no longer worried her. She had earned the right to become their queen. But the struggle had been too great and she died a few hours later.

I felt rather bad about this *Psithyrus* queen, though her death, and the slaughter that preceded it, brought home to me very vividly that these cuckoos, when they force an entrance into a bumble-bees' nest, are the slaves of an impulse more powerful than any urge to protect themselves by flight. They cannot help themselves. If they succeed in overcoming the resistance of the *Bombus* workers, as they must do in the majority of cases, it is neither because of cunning nor stealth, nor because they make use of the wiles and ruses of human parasites, but simply because the bumble-bees lose interest in trying to keep them out.

In the ordinary course of events the cuckoo queen is sooner or later assimilated into the colony of its host. Once this stage has been reached, the workers no longer molest her and she is allowed to move freely about within the nest. But what about the rightful queen? Does she submit meekly to the intrusion of the bold usurper or does she, perhaps dimly aware that all is not well around her, make a bid to restore the peace and harmony of her home? Her daughters have permitted a second queen, one more powerful than their own mother, to creep in and reign beside her.

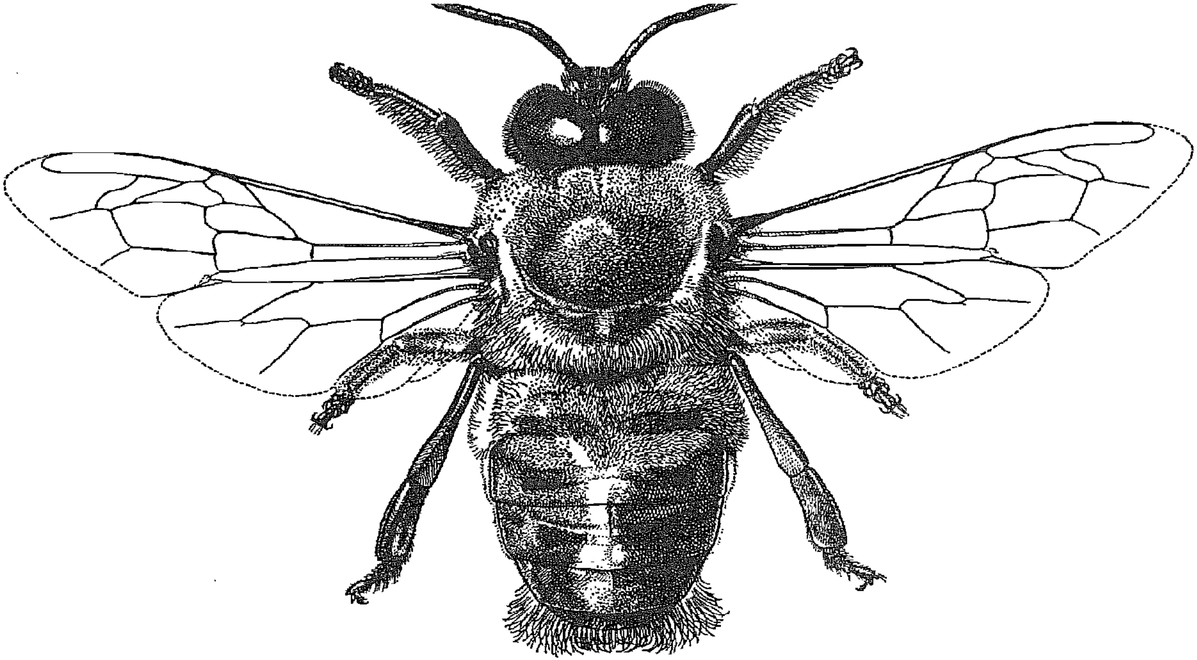


Fig. 9

The male or drone honey-bee, *Apis mellifera*

From a human point of view such a situation could not last; the two queens must surely fight it out. And inevitably victory will go to the stronger, more heavily-armed cuckoo. It would be natural to see in such a decisive combat a necessary step to the final establishment and supremacy of the *Psithyrus* female as head of the colony.

Sladen, who kept bumble-bees in captivity and had many opportunities of studying the behaviour of cuckoo queens, considered that they always killed the *Bombus* queen. He describes with feeling how the queen mother begins to show signs of uneasiness when she becomes fully aware of the parasite's presence within her family. Before long she is wearing a frightened and dejected air as though she knows all too well that she has a rival who intends to oust her. Instead of fussing over her brood in the manner of all good queens, she tries to hide away. Sladen, however, never actually discovered what sort of end she met. Perhaps she really was sought out by the triumphant cuckoo and put to death. Or possibly her own workers, tired of a queen no longer able to carry out her function of laying eggs, and their loyalty divided by the presence of a vigorous *Psithyrus*, in the full prime of her reproductive capacity, moving freely amongst them, attack and destroy her. But however Sladen's queens disappeared, their elimination, he thought, was a proper sequel to the whole sorry business.

Such a story may seem ugly; it robs the ruthless cuckoo of your sympathy, no matter how valiant she may have shown herself in the early stages of her adventure. And you are forced to wonder what strange twist of evolution determined that a hard-working bumble-bee should have her life's purpose cut short on the eve of its fulfilment in order to make room for a race of parasites.

Perhaps Sladen did not see enough of these parasitic bees at work. Perhaps his judgment of the sequence of events was coloured a little too much by his own feelings. At any rate it seems that the intrusion of the cuckoo can take place without dramatic effects. A fight to the death between the rival queens is not an essential part of their conduct towards each other, and in the relations that are finally established between them there is evidence once more that emotions and feelings play no part amongst insects in resolving what to us look like critical situations.

Plath, whose experimental work with *Bombus* and *Psithyrus* goes deeper than Sladen's, considers that the cuckoo never destroys her host. In many colonies he found the two queens living side by side in apparent harmony. He also discovered the even more interesting fact that the bumble-bee queen had lost her significance in the sense that her eggs never developed into bees. If the cuckoo queen is responsible for this, how much more subtle is her method of destroying her host than by killing her outright!

Once installed in the nest, *Psithyrus* settles down happily with her adopted family. She produces no workers, for enough exist around her to meet her needs. And these bumble-bee workers, incapable of distinguishing the cuckoo's brood from that of their own mother, tend the alien grubs with all their accustomed solicitude.

Eventually the cuckoo's family emerges. It consists of males and females, the latter like their mother in every respect. Both sexes fly from the nest and after pairing has taken place the young cuckoo females hide away for the winter in the same way as the bumble-bee queens.

Of all the insect enemies of the bumble-bee, *Psithyrus* is probably the deadliest. We have seen how she destroys the work of the *Bombus* queen, just when this queen has safely overcome the early difficulties of making a nest and her family is well and truly set on the road to prosperity. You might think that no bumble-bee queen could expect to meet a more formidable foe. And yet, strangely enough, the bumble-bees have to contend with a certain amount of robbery and violence from their own kind.

At the time of founding the colony, when the queen is rearing her first brood, it often happens that another young queen, still searching for a nesting site, will come across the established nest and try to get possession of it. Here the contestants are well matched and, to judge from the number of corpses found in the tunnels leading to bumble-bees' nests, the combats are bloody and fatal. I remember once seeing a queen of *Bombus lucorum* entering a little hole in a rubbish heap in my garden. For days I saw her coming and going, bringing in loads of nectar and pollen. Although she had carefully concealed the entrance to her burrow by pulling fragments of grass and rubbish over it, a queen of the larger and more powerful *Bombus terrestris* discovered it. This queen killed the weaker *lucorum* and took possession of her brood.

The queen *terrestris* turned pirate does not behave like the true cuckoo. She is not, like *Psithyrus*, obliged by an inherited type of behaviour to take this short cut, but if the opportunity arises she finds it quite irresistible. Once she has destroyed the rightful queen and got possession of the orphaned brood, her behaviour is that of a devoted mother. Her maternal instincts are immediately aroused and she is soon taking the greatest care of her ready-made family. When the foster children emerge from their cocoons they make no complaint about their forceful adoption and contentedly raise the progeny of the *terrestris* queen.

North American bumble-bees are just as prone to rob with violence as some of our own. Plath records that he has often found the tunnels leading to the nest lined with the corpses of dead queens. What is interesting about this aberration of behaviour is that it shows how a queen bumble-bee can adapt herself to an unusual situation. It shows, too, that some of the things she does are not determined by what she has done before. For example, the slow and decidedly complex business of finding and choosing a nesting site, the preparation of the nest, the building of the honey-pot and the cell for her first eggs—all can be dispensed with if the queen is lucky enough to get these things done for her.

It is the same with the social wasps that we are all familiar with. Their queens will lose no chance of cutting short their nest-making labours, as I have often enough discovered. In order to observe how a queen wasp brought up her family, I used to prepare nesting sites which I hoped would prove acceptable to searching queens. The bait residence was simply a small cavity just below the surface, covered first with a piece of slate and then a clod of earth. A queen German wasp, *Vespula germanica*, soon found the entrance to the tunnel that I had bored through to the cavity and began to build her nest. When I removed this nest three weeks later there were two queens in it, one in excellent fettle, the other dying from a sting. In the tunnel were the bodies of eleven queens. Each of these queens had the full potentialities for making her own nest, but somehow the presence of an existing nest with its special odour, and its warm, live brood was like a magnet to them, and each was ready to fight for possession of it. Whether the vigorous queen in the nest was its rightful owner I do not know. Under my care, and removed with the brood to a place where other wasps could not disturb her, she eventually became the mother of an exceedingly prosperous colony.

To return for a moment to *Psithyrus*, we find that some species can breed only with one particular species of bumble-bee, while others are more catholic in their tastes and have their families raised by several different kinds of

Bombus. In Great Britain, *Bombus lapidarius* is alone chosen to be the host of the cuckoo, *Psithyrus rupestris*. The two queens are so alike that they would deceive anyone who was not an expert in bumble-bees. Of the two, the cuckoo, as befits her dark and crooked ways, is the more sombrely clad. Her wings, instead of being clear like glass, have a smoky stain and her hairy coat is less thick. Altogether she does not show quite the same vivid contrast of scarlet tail and velvety black body that makes *Bombus lapidarius* one of the handsomest of our bumble-bees.

The parasitic habits of *Psithyrus* are a reminder that we should look upon bees with an open mind if only to avoid the possibility of being disillusioned about them.

In the busy comings and goings of bees there is such an air of contentment. They, more than any others, seem to be the ideal insects, roused to anger and defending themselves only when their peaceful activities are interfered with. Could we not keep up the illusion and dismiss the behaviour of *Psithyrus* as the inevitable exception and the piracy of one *Bombus* queen towards another as an occasional lapse of good behaviour? Unfortunately, the fall from grace is bigger than that, and the unsocial habits of the cuckoo bumble-bees are echoed widely throughout the whole world of bees.

Chapter Fourteen

MORE CUCKOOS

When we finished the story of *Psithyrus* I hinted that there were other bees with similar parasitic habits. As a matter of fact there is a whole army of them, and they are among the most beautiful and interesting of all.

It seems that the solitary bees have not been spared the fate of the social bumble-bees, for their ancestors have forsaken again and again the road of independence and acquired the habit of battening on their relatives. These cuckoos now exist in great diversity of form and colour, and in their curious relations with their hosts there is much that needs to be discovered and explained. By what steps they have lost, in the course of evolution, the ability to make a home for themselves and must smuggle their eggs into the nests of other bees we can only conjecture. What is a fact, however, is that they are now set upon a path from which there can be no deviation. Like all bees, they need pollen for their young. But the tools for collecting it—the baskets and brushes of hair—have long been lost. In their place the cuckoos have acquired other skills and features that fit them to overcome whatever resistance they might meet in their attempts to place their eggs in the right kind of nest.

The kind of life the cuckoo-bees lead might perhaps be considered degenerate, and carry them eventually to extinction. At any rate, this is the judgment generally passed on parasites. The cuckoo-bees, however, seem a vigorous lot, and in their successful mode of life I myself can see no taint of gradual and inevitable race suicide.

In the seasonal appearance of an insect one is aware of an ebb and flow in the measure of its abundance. As far as bees are concerned, the parasitic species exercise a limited control over the numbers of the rest. A balance exists between cuckoo and host, otherwise there would be a danger of the cuckoos reducing the number of their hosts to a dangerous level and thereby threatening their own chance of survival. If the cuckoos have a particularly successful campaign in one season, their hosts will be fewer in the next and in consequence harder to find. The cuckoos, whose life span must run a prescribed course, will have to search longer for a nest and many of them will fail to find one altogether. They will pay the price of being tied to too narrow an existence, and while they suffer a temporary eclipse the advantage will shift to the victims until these, once more, are in the ascendancy.

One question about the habits of the cuckoo-bee intrigues above all others. How is it done? How does she manage to lay her egg in the other bee's nest? Is it simply a matter of seizing the right moment to slip in when the mother is away, lay the egg and be off? There is no straight answer to this question because the attitude of the victimized bee towards its enemy is never the same for all combinations of cuckoo and host. Generally speaking, though, it is not heroic.

Consider for a moment the slim, elegant bees of the genus *Nomada*. They are extremely wasp-like in appearance, black, banded and spotted with yellow and sometimes touched up with additional red markings. They are popularly known as the nomadic or wandering bees from their habit of flying low over the ground as though searching for something. This wandering flight belongs to the female, and it takes her over the nesting territory of the solitary *Andrenas* in whose nests she lays her eggs. Observers who have seen *Nomada* attending to its nefarious business tell us that *Andrena*, the host, will quietly wait until the parasite is through with her egg-laying. Someone has suggested that there is a special reason for this. *Nomada* is armed with a subtle weapon. She has a strong aromatic scent, and it is the effect of this, not a spineless acceptance of the inevitable, that forces her victim to stand aside.

Not all bees that are visited by the cuckoos behave like *Andrena*. There are some that immediately show resentment if they catch a cuckoo-bee hovering about their nest. They rush at the intruder and drive her off. She returns, of course, for her eggs, in order to survive, must be laid in the nest that the cuckoo recognizes as the right one to receive them. No alternative course of action is open to her. She cannot suddenly mend her ways and decide to provide for her family by her own efforts. For her there is no escape from a type of behaviour that is an inheritance handed down through a long line of ancestors.

The different groups of cuckoo-bees are restricted to particular groups of hosts. The *Nomadas* almost always select their victims within the group or genus *Andrena*. The leaf-cutter bees are parasitized by *Coelioxys*, and *Osmia* is persistently persecuted by stubby little black cuckoos called *Stelis*.

As far as I know, there are no records of serious encounters between these various groups of bees. No matter how clever the tricks of the host bees are for keeping out the cuckoo, she is equal to them all. If she meets with resistance she must, of course, be able to overcome it. The weapon that *Nomada* uses may be her odour. But for most of the cuckoos it is probably a combination of patience and stealth that finally steers them to success. Taking the

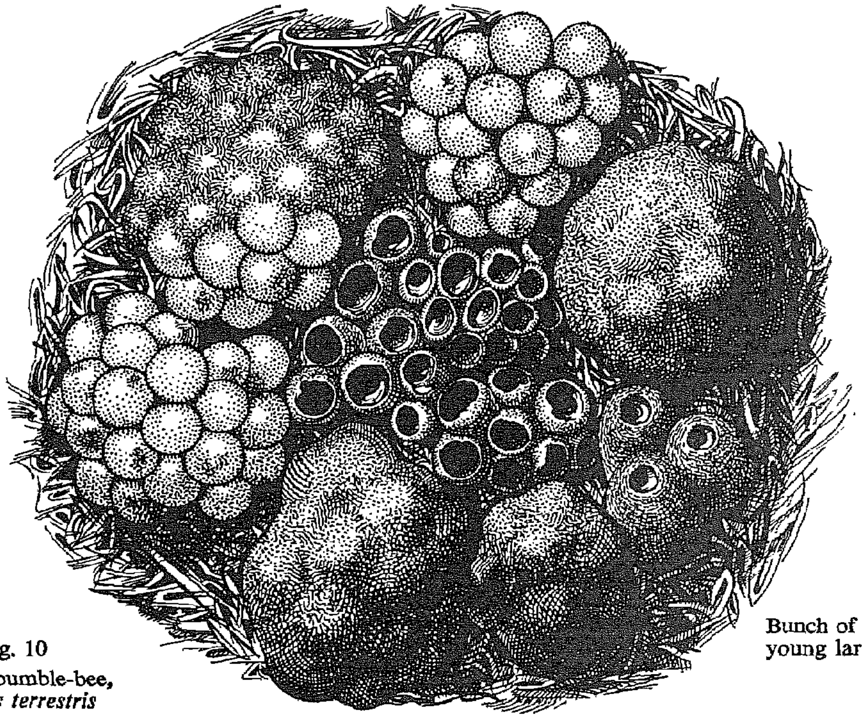

Spinning larvae
In the centre are old cocoons filled with honey
Cluster of cocoons
Bunch of full-grown larvae
Honey pots
Bunch of young larvae

Fig. 10
Nest of bumble-bee,
Bombus terrestris

cuckoo-bees as a whole we find that they are usually armed with a long, powerful sting. It is clearly not to their advantage to use this sting on their host because they would thereby miss the chance of laying eggs in the cells that the host might have built had she lived longer. It is possible that at some time when the cuckoo-bees were being split off by some evolutionary process from ancestors that still retained their full independence, the sting had some useful function. Whether it now helps the cuckoos to free themselves from an occasional rough-and-tumble we cannot easily say.

From all this it looks as if the opposed interests of the independent solitary bees and the cuckoos that parasitize them bring no more than an occasional flicker of passion into their tranquil lives. At least, at first glance this is how it seems. But if we look around far enough we find one exception—one startling exception that shocks by the excess of slaughter with which it is marked.

Many times I have referred to the small solitary bees called *Halictus.* There are hundreds of different kinds and much skill is required to separate one species from another. They, too, have their parasites, small black-and-red cuckoo-bees known as *Sphecodes.* These little cuckoos baffled observers for a long time. They were often to be seen flitting over the ground, sometimes entering burrows but never taking in pollen like the *Halicti* in whose territory they were always seen. Finally it was discovered that they were genuine cuckoo-bees that lived at the expense of the *Halicti.*

How these bees behave towards each other when they meet in the darkness of the burrow is still very much of a mystery. There is, however, the exceptional account to which I have just referred. Legewie has been able to unfold the whole story of how *Sphecodes monilicornis* succeeds in laying her eggs in the nests of her host, *Halictus malachurus.* I give the gist of it not because it is necessarily the normal type of behaviour that exists between *Sphecodes* and *Halictus,* but because I want to cover as widely as possible the range of behaviour that exists between the parasitic bee and its host.

The *malachurus* females are about in early spring after hibernation. They make their nests singly in the usual manner of the solitary bees, and the cuckoo has no difficulty in laying her eggs on the food prepared for the *malachurus* babies. But *Halictus malachurus* is something of an exception amongst its own kind. The offspring that in mid-summer result from this spring activity are all females. And these females, instead of making each a separate burrow, show an approach to true social life in that several of them will often join forces and make a communal nest. They even go so far as to place a watcher at the mouth of the common nest entrance. She, or some other female, is constantly on guard. She is there at the moment when *Sphecodes* arrives.

This cuckoo-bee, for all her small size, is a warrior; or perhaps we should describe her more aptly as an amazon. She is splendidly equipped with the ruthless courage needed for her task. Without wasting a moment, she comes to grips with the patient watcher and soon kills her. And she goes on killing and killing until she has killed all the *Halictus* females as they come forth to attack her. Their bodies are dragged out by the victorious *Sphecodes,* who now becomes the undisputed owner of the nest.

The *Halictus* females, in making a communal nest, show, as I have said, an approach towards social life. But they also make another advance beyond the normal habits of the solitary bee, by leaving open the cells in which their young are developing. *Sphecodes,* once she has got possession of the nest, lays her eggs in these open cells, and then, just in the manner of the normal solitary female but not the cuckoo, carefully closes them. And what is more, she carries her unorthodoxy much further, according to Legewie, by sealing up the mouth of the burrow.

Sphecodes monilicornis, then, is by no means an ordinary cuckoo. There is nothing furtive about her behaviour and she employs neither stealth nor cunning in achieving her purpose. She is the bad, bold pirate and defies us to use the word degenerate in describing her behaviour.

Before we leave the cuckoo-bees there is one other question that ought not to be left completely unanswered. If the cuckoo lays her egg in the cell before it is closed by the mother bee, why does the mother bee not remove it? The question does not really become troublesome if we think of the behaviour of an insect as determined by forces much less complicated than those which govern our own conduct. Even if the host is aware of the presence of her enemy and has even had a skirmish with her, we have no reason to suppose that she has any awareness of the purpose of the cuckoo's presence. So that if the cuckoo can slip in when the host is away and lay her egg at a time when the behaviour of the host has passed beyond the stage of cleaning and preparing the cell, and her energies are now all directed towards gathering in a store of food, the egg of the cuckoo will be safe from interference. The little black cuckoos called *Stelis* have the tip of the abdomen strongly rounded and blunt. As far as we know they lay their egg in the cell of the host, *Osmia*, before the latter has laid in her complete provision of food. The host finishes her work mechanically, laying her own egg on the pollen mass and sealing up the cell. A neat little situation has now been produced with decided dramatic possibilities—food that is enough for one, and two to eat it. The cuckoo grub has a start and hatches first. She begins to eat her way through the loaf of bee-bread towards the rightful baby. There is no fight. These plump bee grubs, whether of host or parasite, are ill-fitted for active violence. The *Stelis* grub evidently possesses some small advantage. Perhaps it is already a little bigger, a little more vigorous than the *Osmia* grub. Perhaps—even more likely—its reaction to a stimulus is a shade faster. At any rate, it plunges its mandibles into the soft body of its feeble competitor and sucks it dry, passing without obvious disturbance from a vegetable to an animal diet.

Not all cuckoo-bees behave like *Stelis*. They prefer to wait until the cells of their host have been fully provisioned and sealed up before they lay their eggs. They then carefully make a hole in the plug, insert the tip of the abdomen and introduce an egg. This must be done while the host is still building cells, and we can imagine that the cuckoo needs to be both quick and cunning to smuggle in her egg when the host is away. Many of the cuckoo-bees are specially adapted for dealing with this delicate operation, laying an egg through a small hole in the plug of the cell. *Coelioxys*, the parasite of the leaf-cutter bee, has the tail end of the abdomen drawn out to a fine, hard point that can be thrust quite a long way through a small opening in the plug of leaves with which the leaf-cutter seals her cells.

You might expect the cuckoo-bees to be somewhat dowdy in appearance. Many of them are. *Coelioxys* and *Stelis* are nearly always black, but the species of *Exaerete*, parasites of the South American bees called *Euglossa*, are sometimes a dazzling metallic green and sometimes they gleam like burnished copper. And then there are the numerous species of the genus *Thyreus*, black but conspicuously dappled with patches of blue or white scales or hairs. Why some of these cuckoos should be so brightly coloured I do not know. Speculation may provide some sort of answer, but the true reason, I think, lies too deeply buried in the past to be satisfactorily explained.

The dappled species of *Thyreus* parasitize the solitary bees called *Anthophora.* They are mostly inhabitants of the tropics and are very common in Africa. As you travel northwards into a more temperate climate, they become scarcer and scarcer, and their place is taken by their close —but far less showy—relatives *Melecta.*

Two kinds of *Melecta* are found in Great Britain. They also victimize the bees of the genus *Anthophora.* Wherever there are colonies of *Anthophora pilipes*—its jet-black females love to nest in the crumbling mortar of old walls —the grey and black, slow flying *Melecta* is likely to be around. Both bees used to be common in the London garden where I grew up. One year the cuckoos swarmed over a bed of wallflowers. Catching them in my fingers, I learnt that the sting of *Melecta* is painful.

Chapter Fifteen

THE ENEMIES OF BEES

THE cuckoo-bees that creep into the nests of their hosts, appropriating for their own use the carefully laid-in provisions, are not the only troubles that bees have to contend with. The activities of the cuckoos account for only a part of the wastage of bee life. The biggest enemy of all is probably the changeability of the weather, at any rate in the more temperate regions of the world. There are plenty of other enemies, too, and they all take their toll of life in accordance with their mode of attack. We can start with the bacteria though we need not linger with them. All who have had much to do with the honey-bee will be familiar with the bacterial disease that makes fatal inroads into its health, destroying its brood and ultimately bringing chaos and disaster to its well-ordered colonies. Then there are the various moulds or fungi that seem best to thrive when sickness has already come to their victims and lowered their resistance. One of these moulds attacks the grubs of the honey-bee, enveloping them in a mass of fine white thread-like growths that cover the corpse like a bung of cotton wool.

These agents of disease, the bacteria and the moulds, are indirect in their action. They attack in a way that makes active defence against them virtually impossible. How they do finally come to get control of a bee or its grub, causing it to sicken and die, is a complicated story whose details are still not fully known. In any case these are not the bee enemies with which I am chiefly concerned. We are going to stay in the sunshine with our bees and see some of those other enemies at work—insects that attack the bees in order to use them as food for their offspring.

Already I have pointed out that bees share a common ancestry with wasps, and how, for a long time, they have been evolving along lines of their own, having forsaken their ancestors' diet of flesh in favour of food obtained entirely from plants.

If we put bees alongside of wasps and try to make a few very general comparisons between them we are struck by one feature in particular. A fiercer struggle to live marks the habits of the wasps. They need to hunt their prey and be able to overpower it.

A wasp is not merely the insect that makes a nuisance of itself by damaging fruit at the end of summer or by building its nest in awkward places—the active, much maligned little creature that so soon causes the passengers in a crowded bus to stir uneasily if it happens to get swept in through an open window. This is just a worker of one of the social wasps. These, like the social bees, are very much in a minority. Great Britain, with a somewhat poor insect fauna, has round about 170 different species of wasps, of which only seven are social in habit. The rest labour like the solitary bees, their females carrying out single-handed the tasks of nest-building and provisioning.

Social or solitary, all these wasps have a sting, though it is not for all of them a weapon of defence. The social wasps certainly use their sting in defence of their homes. It has no other function than to discomfort and rout the enemy. But for the females of the solitary wasps the sting has another, and much more important, use. It is the organ with which they attack their prey and reduce it to impotence. The wasp uses the sting as though it were a hypodermic needle, injecting into her insect victim a small dose of poison that does not kill but has the property of reducing the victim to a condition of paralysis.

The solitary wasps that use their sting in this way are skilful hunters, for they always seem to find just the particular insect they want. In their choice of prey they range over the whole of the insect kingdom and even beyond into the domain of spiders. The *Pompilid* wasps prey exclusively on spiders.

It is because there is almost no kind of insect that some solitary wasp or other does not make use of that wasps come into our story. There are some that prey only on bees. Such is *Cerceris rybyensis*. In the localities this wasp favours, dry, open country with sandy paths, she plays havoc with our small black *Halictus* bees. It is only these that suit her purpose. They are snatched up as they forage among the flowers, quickly stung and borne off, paralysed and helpless, to the wasp's burrow. As many as the female considers sufficient for one of her young are stuffed into a cell, there to be consumed, alive and still fresh, by the wasp grub as soon as it hatches from its egg.

There is another hunting wasp with a fondness for bees. This is *Philanthus triangulum*. Her taste is more catholic than that of *Cerceris rybyensis*, but she nevertheless shows a heavy preference for the honey-bee. *Philanthus* pounces upon the bee as it forages heedless of danger among the flowers, seizes it round the neck with its pair of long sickle-like mandibles and gives it the fatal thrust. The wasp is extremely rare in Great Britain and is confined to a few localities in the extreme south. But on the continent of Europe it is common and also notorious, having earned for itself, through attacking so persistently the honey-bee, the title of bee-wolf.

The bumble-bees, too, have not escaped the attentions of the solitary wasps. The oppressor this time is a wingless

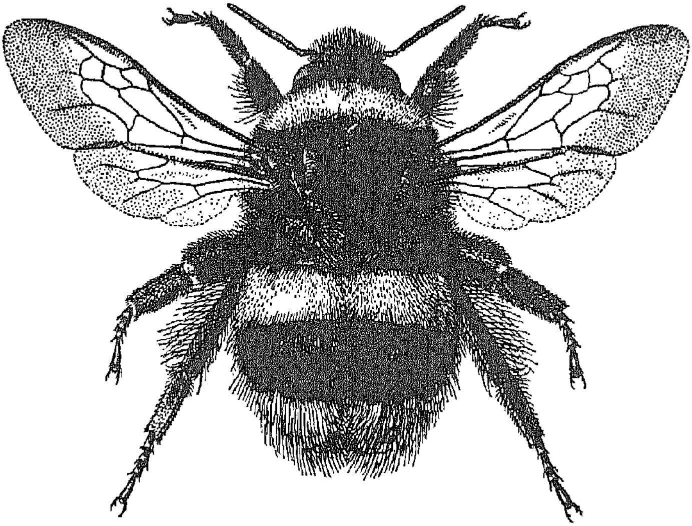
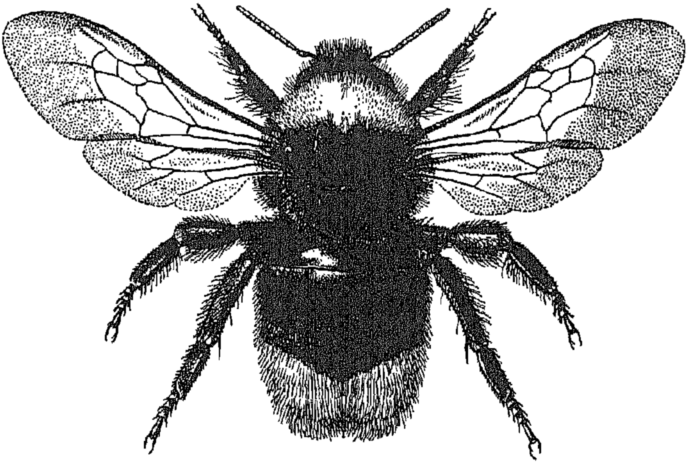


Fig. 11

Queen of bumble-bee, *Bombus terrestris*



Female of cuckoo bumble-bee, *Psithyrus vestalis*

insect that has no use for the techniques of the chase, but she is one of a big family, the *Mutillidae*, or Velvet ants, as they are sometimes called. These wasps are nearly all inhabitants of the hotter and drier parts of the world. Towards the north they become scarcer, and in Great Britain there are only two species, one of which, *Mutilla europaea*, lives at the expense of the bumble-bees.

The Mutillids are peculiar in that only the males have wings. The females, which bear but little resemblance to their mates, are rather like large ants in general appearance. But whereas ants tend to be soberly coloured, the Mutillid females wear a bizarre and conspicuous pattern. On a ground colour that is nearly always a contrast of black and red, they are sharply marked with spots and bands of dense white hair.

In order to provide for their families the Mutillid wasps spend much time running or crawling over the hot bare earth or sand in search of the nests of their prey. Dog does not eat dog, but these wasps prey on the grubs of other wasps, such as the solitary wasps that themselves have preyed upon other insects. The Mutillids also destroy the solitary bees, though *Mutilla europaea* exploits only the bumble-bees. Nothing seems to be known concerning the means she employs of insinuating herself into the bumble-bee colony, but once there she must find ample opportunity for laying her eggs just where they can feed undisturbed on the grubs of the bumble-bee. It is on record that a nest dug out of the ground produced seventy-six Mutillid wasps and only two bumble-bees—convincing proof that the mother wasp must have had some special way of coping with the interference of the bees as she moved from place to place laying her eggs.

All these wasps are adapted to their particular way of life. There is nothing haphazard in their search for victims, nor is there anything especially dramatic in their manner of subduing them. It is the whole intricate pattern of their behaviour that appeals to our imagination. What is obscure, and at the same time exciting, is why every generation of *Cerceris rybyensis* should seek its sustenance in the bodies of bees, while a close relative, *Cerceris arenaria*, is content to feed its young on unappetizing beetles of an unusual hardness. As for the little bees snatched up by the wasp, they are not aware of the danger around the corner. There is no life-and-death game of hide-and-seek between the captor and her prey. The bees are an absolute necessity to the wasp for the continued existence of her kind, and in the scheme of things it is natural that she should collect them with much the same ease as the bees themselves gather their pollen from the flowers.

The term 'wasp' is vague even to a Hymenopterist. Besides the wasps that I have just mentioned there are a vast number of other four-winged Hymenopterous insects which go by the name of 'wasp', though in the classification of the whole order Hymenoptera they are far removed from the stinging wasps that belong to the section Aculeata. They are parasitic in habit and the organ which the bees and wasps use as a sting has retained its older function of being an instrument for laying eggs. Instead of a poison or a paralysing drug passing down the hollow sting, this organ becomes the actual passage through which the egg passes. The parasitic Hymenoptera are a most diverse assortment of insects, some as small as a pin's head, others, like the ichneumon-flies, often as big as large wasps. They lay their eggs as a rule in the living bodies of their hosts by piercing them first with the sharp ovipositor, or egg-laying instrument. How effectively they go to work is shown by *Apanteles glomeratus*, a small black Braconid wasp that lays its eggs as many as fifty at a time in the very young caterpillars of the Large White butterfly. The grubs live inside the caterpillar's body, feeding on its juices but not, apparently, causing it any serious inconvenience. They are full-grown just when the caterpillar is itself full-grown and about to find a place in which to turn to a pupa. At this time they bore their way out through the skin of the host and spin each a little saffron yellow cocoon alongside the now shrunken body of the caterpillar. Eventually the little black wasps emerge from the cocoons and go in search of more young caterpillars.

I have brought in this fragment of information about the Parasitic Hymenoptera only in order to introduce to you the Chrysids or Ruby-tailed wasps. Although they are classified among the Aculeate or stinging Hymenoptera they are somewhat intermediate in their habits between these and the parasitic wasps. They have no sting with which to cause pain. You can pick one up but it will be powerless to hurt you. What you will notice if you can pluck up enough courage to take hold of a Ruby-tailed wasp in your fingers is that it thrusts out from the end of its body a long, extremely mobile and flexible tube. This tube, for all its fearsome appearance, is a rather complicated structure that functions as an ovipositor and is used, not as a piercing instrument, but as a tool for placing an egg in some particular spot in the nest of a bee or a wasp.

The Chrysids are so intimately connected with the lives of the solitary bees, by virtue of being among their worst enemies, that they deserve a special mention. In appearance they are all brilliance, jewels in a metallic green that sometimes merges, towards the tail end of the beast, into a fiery red. They are active only in hot sunshine, and to find them you must go to the wooden posts, the old walls and the sandbanks where the solitary bees make their nests. Here you will see them, running in short, swift spurts, with antennae rapidly vibrating, as they search for the nests of the bees. Like the cuckoo-bees, the Chrysid wasps have been set upon the path of exploitation in order to provide for their young. Although they lay their eggs in the cells of bees, their grubs have no liking for a diet of nectar and pollen. They prefer to wait until the bee larva has consumed the bee-bread and converted it into its own body substance, and then at a chosen moment fasten onto the plump, full-fed grub and suck it dry.

Although these Ruby-tailed wasps are common insects, attracting attention because of their flashing colours, the details of their habits are by no means fully understood. There are many different kinds. What is common to the habits of nearly all of them is that they lay their eggs in the nests of the solitary bees and the solitary wasps. When this much has been said, there still remains the question as to how the eggs are laid in the hosts' nests and what attempt, if any, the rightful mothers make to protect their offspring from this particular kind of destruction. I confess that I can make no generalization here. Instead, I propose to go once more to the work of Ferton and see what he has to say about the methods employed by the female Chrysids to achieve their aims and the efforts the bees make to frustrate them.

There is the case of *Chrysis dichroa*, a parasite of the bee *Osmia rufohirta*, a native of Southern Europe. The bee looks upon the wasp as an enemy and, according to Ferton, does not hesitate to drive it off if she meets it too near her nest. The wasp seems to be truly cunning, for it hides behind a pebble or a twig, waits until the bee goes off on a foraging trip and then slips into the snail shell where the bee is making her cell and lays its egg there. If the wasp should be impatient or indiscreet and approach the shell while the bee is within, the angry mother will assault it vigorously and send it about its business. At Bonifacio, in Corsica, Ferton sometimes saw as many as three wasps watching an *Osmia* at her work.

Now, if each lays an egg in the same cell there is going to be trouble because each Chrysid grub needs a whole bee grub to itself. The difficulty resolves itself finally with chance and battle deciding which of the wasp grubs shall have the whole meal.

When it first hatches from the egg the grub of this particular Chrysid wasp is a minute, active creature with a hard head, a body thickly covered with protective bristles and a pair of sharp, sickle-shaped mandibles. Amongst wasp grubs it is exceptional, for these, like the larvae of bees, are normally soft, legless and incapable of locomotion. The mobile larva of *Chrysis dichroa* is perfectly adapted to the hazardous life it leads during the first few hours of its existence. It is, indeed, made for fighting.

If, in the cell, there should happen to be two or more of these restless first-stage grubs, as they are known, they will sooner or later meet and attack each other. The advantage goes to the one that is quickest to use its sharp mandibles. Once it has buried them in the body of a rival, the rival is quickly sucked dry. When finally the whole field is secured by a single victorious grub, it loses no time in attaching itself to the helpless bee larva, choosing the moment when this has finished feeding, and is about to spin its cocoon.

Securely anchored by its mandibles to its living food supply, the wasp grub moults and becomes a passive grub, different from its former self, no longer endowed with the power of locomotion and intent only on satisfying its appetite. None of the movements made by the unlucky bee larva as it spins its cocoon is able to dislodge the enemy. The two are woven in together tightly. As for the bee larva, nothing can save it now. It gradually shrinks in size while the parasite grows plumper and plumper.

Eventually the wasp grub is full grown and turns to a pupa. Next year it bites its way out of the cocoon so conveniently made for it by its victim, and flies away.

We will let Ferton tell us about one more Ruby-tailed wasp and then leave them, for in spite of their brilliance there is something faintly horrific in their manner of exploiting their unfortunate hosts.

Again the host is an *Osmia*—a species called *saundersi.* This bee makes her cells in the ground and lines them with pieces of petal cut from a yellow flower. The finished cell is sealed with further pieces of petal and the little hole at the bottom of which it lies is filled with sand by the mother bee to a depth of a quarter to half an inch.

At the time when the bees are working at their nests a Ruby-tailed wasp, *Chrysis prodita,* is about also. But the wasp seems to be in no hurry to lay her eggs and pays no serious attention to the matter until the *Osmias* have finished their work, or even disappeared. It is now the end of July or the beginning of August. The hot sun keeps the sand over the nests of the *Osmias* loose and dry. This is the time when the wasp goes forth in earnest to search patiently for the cells of the bees. The bee larva must be just at the right stage of its development, full-fed and resting quietly within its cocoon. The wasp digs down through the sand, bites through the plug of petals and finds the cocoon. By a strange irony of fate a peculiarity in the texture of the cocoon, designed to help the adult bee to emerge more easily from it, now aids the parasite to reach her prey. The weave is thinner at the top, and it is here that the wasp bites a hole through which she afterwards inserts the long flexible tail-end of her abdomen in order to lay an egg. The newly-hatched grub is not active like that of *Chrysis dichroa.* It does not enter life equipped for violent struggle, for there is very little likelihood that there will be a second grub competing with it. It feeds rapidly and in six days has completely devoured its host.

In the two accounts I have given there is a big difference in the behaviour of the female wasps at the time of egg-laying. The first, *Chrysis dichroa*, has to wait and watch, ready to seize the first opportunity of entering the nest of its host in order to lay her eggs. The second, *Chrysis prodita*, employs an entirely different technique. She never comes into contact with the parents of her victims. Guided instead by special sense organs she goes in search of the buried cells of the bee, selecting only those in which the bee larva has entered a resting stage. There must be a reason why the wasp chooses her host just at this stage of its development. Ferton suggests that her delicate egg might get crushed in the cramped quarters of the cocoon if the host were still capable of vigorous movement. He adds also that the wasp is not particularly skilful at finding bee grubs just in the right condition. She spends quite a lot of time digging down to the cocoon, only to abandon her labours because things are not to her satisfaction.

Chapter Sixteen

ARE BEES AGGRESSIVE INSECTS?

It is natural enough to think that bees ought to be spiteful simply because they are armed with a sting. And yet, taken as a whole, they are far from being aggressive insects. In fact, it is hard to imagine what function the sting can possibly have for most of them.

The sting, as we have already seen, belongs to the female only. The male is without weapons of defence. For him the only means of self-protection is by escape in flight. Since he has only his person to protect, the means are doubtless adequate. The female is in a very different position. She has heavy responsibilities. The safety of her family depends on her, and it seems right and proper that she should be able to defend it. But in actual fact does she defend it? Or to put it more accurately, when danger threatens what proportion of all bees does use its sting in defence of its nest?

The solitary bee is beyond doubt a timid insect. You may dig out her nest and leave it a ruin. You may violate her maternal privacy while she is at home, poking at her with a grass stem or pulling at her with a pair of tweezers, but even then she will forbear to attack you. She will, on the contrary, make every effort to escape so long as there is enough warmth in the weather to rouse her legs and wings to action. It is not that her sting has lost its needle sharpness or that she cannot charge it with venom. You can test this for yourself by picking her up between your fingers. Whether you feel the sting or not depends very much on the species

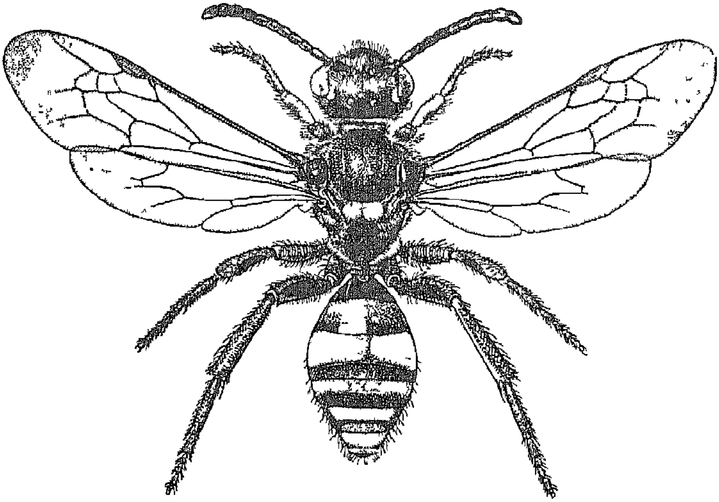
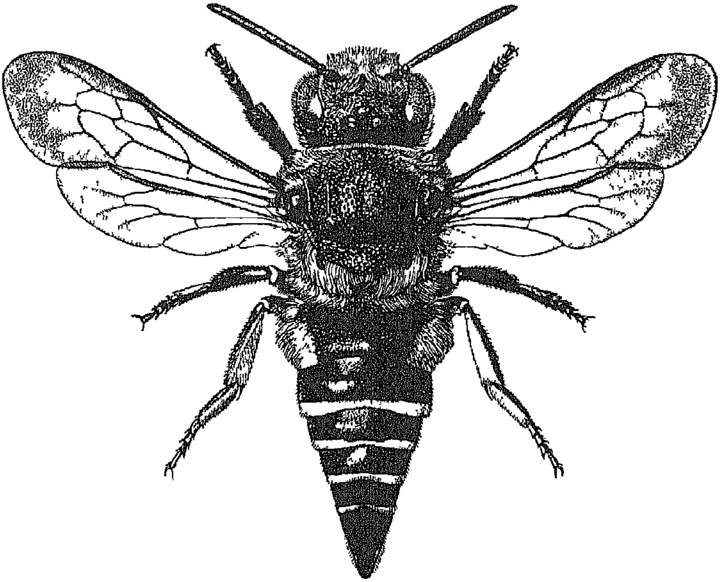


Fig. 12
Nomada leucophthalma Kirby
Cuckoo-bees
Coelioxys elongata Lep



of bee. The diminutive *Halicti*, which are generally somewhere between a quarter and a half inch in length, are not very likely to have a sting firm enough to prick your flesh. But get hold of one of the larger solitary bees—*Andrena, Osmia* or *Megachile*—and the chances are that the sting will pierce your skin. Although I have been stung by various solitary bees, I have never found the result particularly uncomfortable. My experience, limited to the bees of Great Britain, has been that the smaller the bee the less painful its sting. The larger and more powerfully built species have a sting that is thicker and less flexible in proportion and hence better able to penetrate more deeply into human flesh. This generalization should not be taken too seriously. I should be most unhappy if any of my readers went around picking up small bees with full confidence that they would not be stung.

All this is only indirectly connected with the problem of the moment, which is to find out whether bees, because they have a sting, are temperamentally aggressive insects. Apart from the occasional rough-and-tumble when a female solitary bee accidentally enters the burrow of her neighbour, fighting is not a part of the behaviour of the solitary species.

It has already been emphasized that bees, as far as the evidence goes, are descended from carnivorous wasp-like ancestors. Their ancestors doubtless had a use for their sting, but since they took to a vegetarian diet the sting, though still retained, has ceased to have a special function. To the vast majority of wasps, as I pointed out in an earlier chapter, the sting is not a weapon of defence but an instrument by means of which they inject a venom that paralyses the nervous system of their prey. Among the social wasps the sting has become an organ of defence, just as it has in the honey-bee and the bumble-bees. If we are going to think of bees in terms of aggressiveness, then it is these social bees that will throw some light on the quality of a bee's temper.

To find the bee that indeed attacks, coming at you so fast that you are unaware of the danger until you feel the sudden agonizing pain on lip or eyelid, you must go to the genus *Apis*, the name that covers the world-wide honey-bee, *Apis mellifera* and her two close relatives, the Giant honey-bee, *Apis dorsata*, and the Little honey-bee, *Apis florea*, both of which are natives of the Far East. The common honey-bee, the bee in essence on which all judgments about bees are made, is certainly one of the most uneven-tempered of insects. She makes the fullest use of her sting in defence of her home. This is to be expected. But sometimes she seems to flourish it for no other reason than that the prevailing weather makes her irritable or that she comes from a long line of touchy ancestors.

Aggressiveness in the honey-bee is a decidedly variable characteristic. There is not the same amount of it in the bees of two colonies and it varies from race to race. By race I mean the whole population of honey-bees that has existed in some geographical region of the world for countless ages, cut off by climatic or physical barriers from other populations of honey-bees and not yet transplanted from one part of the earth's surface to another by man himself. For instance, the race that occurs in Carniolia in Central Europe has the reputation of being extremely good-tempered —that is, good-tempered according to the standards of beekeepers. Another gentle race is the Italian, though perhaps you had never thought so. Should you happen to talk about bees to anyone who is sufficiently interested to listen and even make the odd comment, he is almost sure to say that Italian bees are excitable and bad-tempered. In reality he is expecting his curious notions about the Italian people to apply also to the bees that come from their country.

Other races of the honey-bee will attack almost on sight and, at the slightest disturbance of their hive, boil out in vicious, spiteful hordes. It is not really surprising that the bees we keep in our hives are often of doubtful temper. After all, they carry in their blood a mixed heritage of the good and bad qualities of the various races that enterprising beekeepers have brought here from time to time. And since until recently it has been well-nigh impossible to exercise any control over the mating of the queen honey-bee, heredity has shuffled in endless variety the inherent characteristics of all these races.

It is natural enough that the honey-bee should sting when her home is interfered with. What we should all like to know is how far we can trust her not to use her sting when she is away from the hive, going about her business. It is fairly safe to assume that the aggressiveness of a bee is a part of its behaviour when it is actually forming a unit of the colony to which it belongs. The presence of sister-workers, the queen, the warm brood and the nest odour—all play some part in deciding how it shall behave. But when it exists as an independent individual, working among the flowers, its ties with the parent community are severed and the only link between the bee and the colony is the memory of the nest site. At this time our bee is likely to be as timid as the solitary bees with which it competes for food. Provided there are flowers to their liking, honey-bees forage everywhere, in gardens, in the open country and even in the heart of a town. Stand under a cherry tree in full bloom on a sunny day in April and you will hear their steady murmur. But whoever heard of such a pleasant experience being marred by the sudden attack of an ill-tempered bee?

Sometimes beekeepers leave combs of honey about, or leave them insecurely protected from the sugar-hungry bees. Once the treasure is discovered, the bee loses no time in informing her sister workers. Within minutes, almost, they are arriving in hundreds to gather the harvest. Should they now be discovered at their pilfering and refused further access to the sweets, they are likely to become irritable and aggressive.

As for the bumble-bees, when away from home they are among the most peaceful of all insects. No matter how much you deliberately try to worry them, they will never attack, but instead dash off in headlong flight. Short of pressing its business end against your own skin, you can provoke a bumble-bee to sting only by disturbing its nest. Then, whatever viciousness is latent in the species will rise to the surface. It is a variable thing, this viciousness of bumble-bees, and is strong or weak according to the species. Some kinds are so timid that you can plunder their homes without fear of reprisals. Others are extremely spiteful if such liberties are taken and will follow their persecutors for a long way, inflicting stings which Professor Plath thinks are sometimes more painful than those of honey-bees and wasps. One of the least amiable in disposition among our bumble-bees is *Bombus terrestris*. When, many years ago, I used to keep the nests of bumble-bees, this was the species that stung me more than any other, though I do not recall that its sting was especially painful.

The little brown bumble-bee, *Bombus agrorum*, that makes its nest in mounds of dry grass on the surface of the ground, is a gentle creature compared with *Bombus terrestris*. It makes a loud sizzling or buzzing noise if its nest is disturbed, but though I have peeped into the nests often enough and sometimes taken the whole colony home, the bees have never flown to the attack. When hard pressed they have, however, a curious way of defending themselves; they turn over on to their back, raising either one or the other of their middle pair of legs in a warding-off attitude if any object is brought near them. If you should accidentally touch one while it is lying on its back you will certainly be stung. But this is self-defence pure and simple and falls outside the definition of aggressiveness. When I wanted to collect all the bees in a nest, I used to pick them up with a pair of forceps when they adopted their upside-down defensive attitude. This was less easy than it sounds because the bees kept their legs cleverly out of the way of my forceps by a slight but rapid change of position.

All things considered, it seems that bees, apart from honey-bees and some bumble-bees, are harmless insects, seeking safety in flight and never deliberately using their sting unless actually held between the fingers or against some part of the human body. The thrusting-out of the sting in these circumstances might almost be called a reflex action. It is certainly extremely doubtful if the bee expects to free itself from its captor's clutches by using its sting in this way.

Apart from honey-bees, whose motives in any case are suspect, bees often have a habit of buzzing around one's head. The handsome black-and-red bumble-bee, *Bombus lapidarius*, is fond of doing it and a sinister intention is always feared. I do not know what causes this kind of behaviour. I have noticed it also among our social wasps, more especially in the tree wasp, *Vespula sylvestris*. Its workers sweep threateningly from side to side in front of us, should we happen to cross their line of flight. Or so it has often seemed to me. And yet this wasp is one of our less aggressive species. The German wasp, *Vespula germanica*, on the other hand, which I have never known to buzz around my head, is extremely—almost relentlessly—aggressive if you break into the site of its nest.

Bees and wasps are creatures of temperament. They show varying degrees of excitability and the way they react to a situation is certainly not the same for all species.

Chapter Seventeen

PAIRING AND FERTILIZATION

In his classic work on the life of the bee Maeterlinck has described in beautiful language the marriage flight of the virgin queen. As a matter of fact, however, no one really knows the details of this aerial encounter between the queen and her mate. How high she flies into the blue sky of a summer's day each time she goes off on her lone flights can only be guessed at. Only one thing is certain; on one special occasion she is pursued by at least one male or drone, as he is usually called. Observers are supposed to have seen the drones flying in conical formation in hot pursuit of a queen. Although I have often watched virgin queens fly from their hive, I have never been lucky enough to see a whole band of suitors whirling to the chase. Perhaps it was the brightness of the sun or the difficulty of following so small an insect in flight or possibly my own lack of imagination.

It is often said that the pursuit of the queen by many drones is necessary to the successful maintenance of the species. The swiftest reaches her first and he is presumed, because he has outstripped his rivals in flight, to be also the fittest of the suitors. It is far more likely that the object of this mating in the air is not to ensure that the queen gets a swift mate but that she should have the chance of pairing with a drone that is not from her own colony.

No one, for obvious reasons, has ever witnessed the concluding moments of the chase, but by putting together pieces of factual information concerning the relative sizes of drone and queen and the physiology of the drone himself, we have a pretty shrewd idea of what happens. The virgin is seized in mid-air and the two insects, locked together in sexual union, drift rapidly to the ground. For this embrace, even though it makes possible the abundant renewal of life, comes as a tragic sequel to a headlong and tempestuous courtship. The drone is dead; he is so constituted that he cannot survive the fulfilment of his only function in life. He is dead by the time he has passed on to the queen the millions of sperms that will last her as long as she lives.

Now that mating has taken place, the queen feels an urge to return home as quickly as possible. To free herself from her mate, whose dead body is still firmly attached to hers, she methodically cuts herself loose with her mandibles, afterwards flying back to the hive with the remnants of the male's copulatory organs showing as a shred of white tissue at the end of her abdomen. The worker bees, eagerly awaiting the return of their queen, or, to put it more accurately, reacting with increasing excitement to her absence, receive her back with every sign of satisfaction and soon remove these last encumbrances of her nuptials. About two days later, the queen, who will never leave the hive again until swarming time, begins to lay the fertilized eggs that will become the ever-growing force of workers whose labours will bring prosperity to her colony.

As far as is known, it is only the male of the honey-bee that dies at the time of mating. Owing to the structure of his reproductive organs, death follows almost automatically when they are brought into full use. The aerial courtship seems also to be exceptional among bees, though here we are on less firm ground because relatively little is known about their mating behaviour. Both queen and drone are in flight at the same time. The male actually seeks the virgin in the air and while he is engaged in these amorous quests he has never been known to settle or refresh himself at a flower. The only port of call for the drone is his own hive. Here there is warmth and food in plenty.

The mating of the bumble-bees seems to be altogether less spectacular than that of the honey-bee. It is probable that the males of some species settle at some vantage point from which they fly up at passing females and seize them in the air. It is difficult otherwise to explain the behaviour of *Bombus separatus*, an American species whose male, so Professor Plath tells us, sits at the alert on the trunks of trees and similar objects and darts swiftly at insects flying within range of its vision. The habit of darting at other insects is common among insects generally and probably represents an attempt, mostly abortive, on the part of the male to find a mate. It is a sharply defined and well-known habit among some of the two-winged flies of the order Diptera. Many males of the Syrphidae, popularly called hover-flies, hang almost motionless in the air, like diminutive helicopters, and every now and then sweep off in pursuit of a passing insect, mistaken presumably for a female, only to return as quickly to what seems to us almost the same point in space.

Bees are high-powered insects that live furiously. Unlike other insects, they not only depend on fine weather for full activity but their females must also, during sunny spells, carry out an immense amount of complicated work. This is especially true of the bees of the temperate regions. How they behave in the tropics I do not know, though I believe they tend to cease work during the hottest part of the day. The males, too, are active creatures, spending long periods in flight as they search for the females. They hunt by sight and their lovemaking is characterized by an impetuosity that leaves no room for preliminary advances. There is no posturing, no artful wooing of a capricious virgin. As among insects generally, he who first comes to the banquet

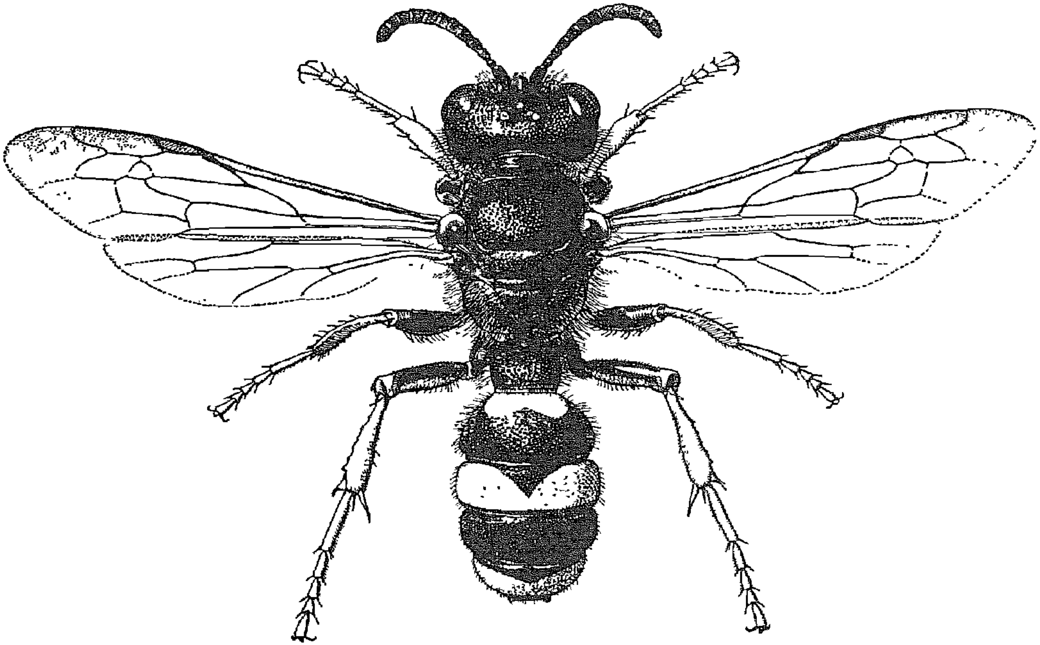


Fig. 13

A solitary wasp that feeds its young on bees : *Cerceris rybyensis* (see page 136)

gets the whole meal; the female is pounced upon, held in a tight embrace, and sexual union follows at once.

Earlier, when I drew attention to sexual dimorphism among bees, I pointed out that the male is often provided with special means for holding his mate. Long, curved mandibles, for instance, that can be used like a pair of calipers for seizing the female around the neck at the time of pairing are a common feature of many bees. This habit is by no means confined to bees and is met with amongst the Mutillidae, a large group of wasps, mostly tropical, whose females are always wingless. The winged males are often enormous by comparison with their partners. Should one of them find a female responsive to his advances, he grasps her round the neck with his mandibles and will even bear her off with him in flight.

When I was making a collection of bees I made use of the habit the males have of finding their females by sight in order to get a series of the males of *Anthophora pilipes*. The male is a brown bee fond of coursing along a set path just a few inches above the surface of the ground. He is on the look-out for the female who, by contrast, is jet black in colour and quite one of the most elegant of British bees. The male is reluctant to settle and much too quick to get caught in a net. How would it be, I thought, if I could hold his attention long enough to slip my net over him? If it was the blackness of the female that first caught his eye, would a dead one deceive him? I put the matter to the test. As each male careered along the fixed path of flight to where the corpse of a female lay pinned to a piece of cork, he pounced on it with all the eagerness of his youthful vigour. These males stayed just long enough for me to capture them without trouble. Looking back, I cannot help thinking that I played a mean trick on those amorous *Anthophora* males.

Finding the female by sight is probably the rule among bees. Nevertheless there may be examples of courtship where a combination of sight and smell is the means of bringing the sexes together. Dr. Tetens Nielsen, who has made a careful study of the habits of Danish bees, has described the mating of *Colletes cunicularius*, a species that flies early in the spring. The females are gregarious, enormous numbers of them making their burrows in the same small stretch of territory. On sunny days the males fly in hundreds over the nesting-ground, waiting for unmated females to emerge from their winter quarters. A crowd of them can often be seen waiting at a spot where a virgin is about to appear. As soon as she shows her head, the suitors examine her carefully with their antennae. When she is quite free, competition sharpens and the males make every attempt to jostle each other out of the way. After coupling has taken place, there is a change in the female's behaviour. Before, she was passive, almost neutral, but now she shows resentment towards any male that tries to embarrass her with his advances, and does not hesitate, so Nielsen says, to strike out at him vigorously with her back legs.

Searching for the females is not completely random. The males of many kinds of bees have fixed paths of flight or special areas that they patrol. For example, they will course up and down a hedgerow or around low trees and bushes, and if a particular species of bee has the habit of looking for his mate on the leaves of a tree he will certainly not look for her elsewhere. One small *Andrena,* known as *gwynana,* flits low over bare ground looking for the females. Another—*jacobi*—that I knew well as a boy, used to fly in swarms around the topmost branches of a cherry tree in full flower. It was on the trunk of this tree that I used to catch its fragrantly-scented females in the late afternoon.

A curious feature about bees is that the males usually emerge from their cells several days before the females. In *Andrena* and *Colletes* the difference in time is about eight days, but in others, among them *Eucera*, whose males are striking insects on account of their very long antennae, it may be as much as three weeks.

In those species which come out particularly early in the spring, when a run of days fine and warm enough for full bee activity is rare, there is a shorter interval between the emergences of the sexes. It is possible to suggest a reason for this. Should there be a sudden onset of severe weather and the females were delayed too long, they might find that cold and hunger had robbed them of their mates. Later on in the summer the males are exposed to less risk. Even though they may be forced to lead a bachelor existence, food is abundant in the flowers, and the weather is mostly warm enough for them to set out in search of their females.

It has never been seriously suggested that these males are aware that they have a long wait and just bide their time until they have at least a chance of a successful encounter. They go on searching all the time, drifting farther and farther away from their actual birthplace and thereby reducing the possibility of making sexual contact with their sisters from the same nest. In this way the premature emergence of the males, or, if you prefer, the retarded emergence of the females, helps the species to avoid the risks of inbreeding.

It seems to be a general rule that mating, at any rate for the female, takes place only once. The queen honey-bee has been known to take a second marriage flight, but when this happens we must regard her behaviour as exceptional. For normally there is a rapid change in the general pattern of her behaviour after copulation. Her abdomen soon shows a slight but unmistakable increase in size and within two days she has lost most of her virgin flightiness and laid her first eggs. Once a bee of any kind has started to lay eggs, further mating, as far as is known, never takes place. At the time of copulation the sperms that pass from the male to the female are stored in a special receptacle in her body called the spermatheca. Here the sexual cells live for as long as she has need of them, which is roughly the length of her life-span. The queen bumble-bee mates in the late summer or autumn, passes the winter in hibernation and has active sperms stored in her body to fertilize her eggs throughout the following summer. The queen honey-bee does better than this; she may live as long as four years, all the time drawing on a reserve of sperms that she received at the time of her marriage flight.

The reproductive organs of a female bee are so constructed that an egg passing down the oviduct must pass the entrance to the spermatheca before it is laid. If the egg is to be fertilized the female is able to release the spermatozoa at the appropriate time. The egg itself is covered with a thin shell. But at one end there is a minute opening called the micropyle through which the male cell enters in order to unite with the female cell within.

Sometimes the egg is allowed to pass without receiving any spermatozoa at all. The female is then said to have given birth by parthenogenesis; the insect that grows from her egg has been truly born of a virgin in the sense that it is the product of its mother's germ cells only.

There are many kinds of insects whose females can produce offspring without having mated. No better example can be found than the greenfly, or aphids, that seem to multiply as if by magic. One day there is just the odd one sitting beneath the rose bud; within a day or two there are so many of them that they form a green jacket around the stem. Certain generations of these aphid females not only reproduce without the help of a male, but they also hasten their enormous increase by giving birth to live progeny ready to start feeding at once.

When insects give birth by parthenogenesis their offspring can be either male or female, according to the kind of insect. The stick insects that feed on privet and are often kept by schoolboys produce only females. And there are certain beetles and flies that have never been found in the male sex. But when the ants, bees and wasps lay unfertilized eggs it is usually only males that develop from them. On many occasions I have kept small nests of hornets and wasps that contained workers but no queen. After a few weeks males would always be present in these nests. They were the progeny of workers in whom the absence of the queen had produced a physiological change; their ovaries developed and they began to lay eggs that were, of course, unfertilized, for the workers are unable to mate. Naturally the life of such a queenless colony is short and limited to the length of time the workers themselves can live under conditions that are far from natural for them. There is no replacement of a queen among wasps and hornets unless a stray one, who has not yet made her own nest, is adopted. In this respect the honey-bee is much better off. Should some accident befall the queen, the workers can themselves make another one to take her place. They will select an egg or young grub that under normal circumstances would have developed into a worker, and by changing its diet cause it to grow into a queen. But while feeding it differently and more abundantly, they also enlarge the girth of its cell, so that the grub grows to final maturity in circumstances that have been quite profoundly altered.

In 1845 a theory was put forward by Johannes Dzierzon that the drone or male of the honey-bee developed from an unfertilized egg, while the female, whether worker or queen, was the product of an egg into which a spermatozoan had passed. For a long time the theory was hotly contested, but it is true in all its essentials. The drone has no father, though since his mother springs from a union of male and female, he has, of course, a grandfather.

When the queen moves over the combs laying eggs she puts fertilized eggs in the smaller, more numerous worker cells, and unfertilized ones in larger cells, where the drones are raised. When both sizes of cells are available to her she never makes a mistake about the kind of egg to put into each. How she is able to appreciate the difference in the size of worker and drone cell no one has so far discovered.

The queen honey-bee lives, as we have seen, for several years, populating her hive each season with fresh generations of workers and drones. But insects generally are short-lived creatures, and last, at least as far as the female is concerned, only about as long as it takes for their eggs to be laid under conditions suitable for their future development. At one end of the age scale we have a common moth such as the Vapourer, for example. On emergence from the pupa, the curious wingless female stays on her cocoon, mates almost at once, and, remaining just where she is, lays her eggs within a few hours all over the surface of her cocoon. She then dies.

No ant, bee, or wasp could get through its maternal duties as quickly as this. Even those among them whose reproductive life is shortest, such as the solitary bees and wasps, are hardly likely to complete their labours in less than a week or two. And as for queen ants, all of which are social in habit, they live for a long time, and one has even been kept in captivity with successive contingents of workers for as long as fifteen years.

Chapter Eighteen

ARE BEES MORE INTELLIGENT THAN OTHER INSECTS?

WHETHER insects display intelligence such as we understand it in humans is a matter which no two entomologists are entirely agreed upon. There is a school of thought that sees in even the most complicated behaviour of an insect only an instinctive response to a particular condition or set of conditions. The reactions of the insects follow one upon the other in a chain-like series. There is no place here for free will or freedom of choice; the poor insect cannot really help itself, it is a slave to its environment. Consider for a moment the Large White butterfly that lays its eggs on the plants of the cabbage family and sometimes on the leaves of the nasturtium, a plant which to the botanist has only a distant relationship with the cabbage. What is the stimulus that draws the butterfly to these unrelated plants? The answer is that both the cabbage and the nasturtium contain mustard oil, and it is to this oil that the female, with the ripening of her eggs, is chemically attracted. She cannot avoid being drawn to the smell of mustard oil any more than a moth that is attracted fatally to the flame of a candle. This is, of course, a very simple case to show that the behaviour of an insect can be considered as nothing more than an automatic response to the conditions of its environment.

Opposed to these matter-of-fact students of insect behaviour, who, contrary to popular belief, are just as anxious to find the truth as anyone else, are those whose comprehension is constantly baffled by the complex behaviour of insects. Putting themselves in the position of the insects, they have little difficulty in persuading themselves that they would indeed be very intelligent if they could carry out the complicated tasks of a bee or wasp with the same amount of success.

Whether insects are able to make use of past experience in order to meet present difficulties; whether they can modify their behaviour or follow a course of action so that it conforms the better to an idea they have of what may happen in the future, these are questions I cannot answer.

If insects are to be credited with any intelligence at all, then most of it, by common consent, is believed to reside in the brains of the bees, the wasps and the ants. In a sense the social habits of these three groups of insects have caused them to be much misunderstood. Man has delighted in comparing their societies with his own and drawing conclusions that are seldom valid.

The honey-bee has attracted attention from time immemorial because someone once found by chance that it stored a sweet, delicious substance that made eating more exciting. For this reason the society of the honey-bee is looked upon as ideal in every way.

The ants have been less fortunate. For one thing they are earthbound, and furthermore so much of what they do takes place in darkness. But it must have been obvious to the earliest observers that these busy insects, when they did not shun the light of day, showed some kind of co-operation in their movements, and when gradually a few facts came to be known about them, the inevitable comparisons were made. Since the ants confer no obvious benefit upon mankind, they have not, like the honey-bee, been studied with a special bias in their favour; though their industry is some-

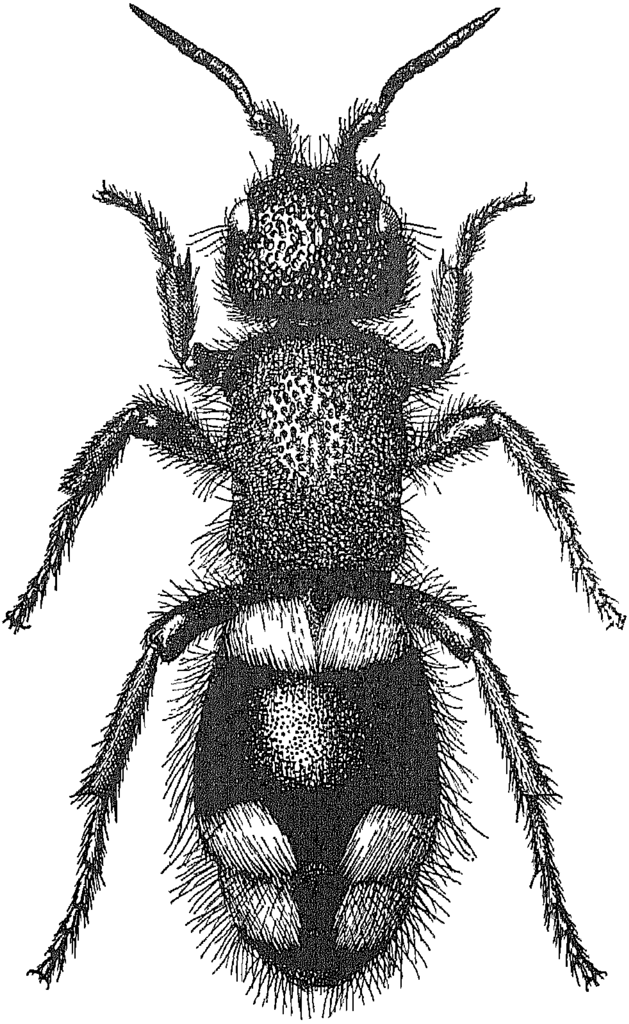


Fig. 14

A solitary wasp, sometimes known as a Velvet-ant that lays its eggs in the nests of bumble-bees: *Mutilla europaea* (see page 137)

times admired, the tendency is always to be faintly shocked by the efficient way in which ants appear to manage their affairs and to see in their beautifully co-ordinated organizations only a grim warning against the evils of the totalitarian state.

As for the fierce wasps, their social behaviour has escaped judgment because so little is known about it. To brave their stings in order to reveal the secrets of their private lives has never seemed a particularly worth-while undertaking. To most people wasps are still much of a mystery. If they have the reputation of being unpleasant insects it is because of their fondness for helping themselves to man's food.

Ants and wasps are outside the scope of this book. If I mention them from time to time it is only because fundamentally the general pattern of their social behaviour is very like that of the bees. This may come as a surprise to people who have been accustomed to regard the society of the honey-bee as unique. It is probable that there is no aspect in the honey-bee's behaviour that is not repeated in some form or another in the behaviour of ants and wasps. In an earlier chapter I laid stress on the importance of a sense of smell in maintaining the cohesion of the bee colony. It is equally important among the ants. The driver ants of the tropics, for example, are totally blind and yet they are able to march in perfect columns hundreds of yards long. If a handful of these ants is thrown down and scattered, they are able to co-ordinate their movements and reassemble themselves as a group in a very short time. If a swarm of bees is shaken to the ground, they regroup themselves in the same way as the ants, though whether the physiological process is quite the same for ant and bee I am not prepared to say. Intelligence, however, finds no place in this particular facet of social behaviour.

In the popular imagination the vote of being the most intelligent of all insects goes naturally to the honey-bee. This is what you would expect in view of its long association with man, and the mixture of awe and ignorance with which its habits and communal life have been regarded. It is no exaggeration to say that the honey-bee is made almost human; a casual perusal of books on beekeeping, even modern ones, is enough to show that she is capable of experiencing joy and sorrow, hope and frustration, and yet all the while is able to control her destiny by the exercise of reason. Truly, if ever an insect were made in the image of man it is the honey-bee. There is, of course, no doubt that she is a very remarkable insect, but whether her curious and often intensely complex behaviour should be taken as proof of intelligence is quite another matter.

There must be very few of us who have not heard of the famous dances of the honey-bee. They have been given plenty of publicity in the Press as well as through the films and the radio.

These dances represent a kind of language whereby the bees communicate with one another, and we owe our knowledge of them to Professor von Frisch, who seems to have spared himself no pains to prove the soundness of his extraordinary discoveries.

A comb of bees, lifted gently out of a hive, may sometimes show a bee absorbed in her dancing. With her body wriggling all the time, she seems to run first in one direction and then in another. Her sister workers in closest contact with her appear to take note of her movements and become rather excited by them. The dancing bee has a message to give them: she has found a rich supply of food and they are now being told where they may find it. The instructions are precise, for both direction and distance are given.

When von Frisch first announced that he had discovered the meaning of the dance and proceeded to explain it, no one wanted to believe him. Even the most devoted and uncritical of the honey-bee's admirers thought he was going a bit too far. Von Frisch modestly admits that what his observations have proved to him reads more like a fairy tale than a statement of bare scientific fact. But the evidence is there, he says, and you can test it out for yourselves. It only requires patience.

But first of all, what are these dances and how much does von Frisch claim for them?

The honey-bee cannot resist sweetness; she is made that way. If a foraging worker is brought to a dish of sugar syrup she fills her crop, carefully takes note of the exact situation of the dish and then flies off home. She cannot keep her secret to herself. Greed and self-interest never cloud the lives of the social insects. Once back on the comb amidst a dense throng of sister-workers, the bee begins to dance vigorously. She is all excitement. It is easy to see, too, that her excitement infects the bees that are closest to her.

There are two set patterns of movement, or dances, one very much more simple than the other, and each conveys different information. If the syrup is not more than fifty yards from the hive the bee performs a round dance. She runs round a circle roughly the size of a penny, taking first a few turns in one direction and then a few in the other. According to von Frisch the bee is telling her companions as plainly as she can that they must hurry out and search for the food round about the hive within a circle of not more than fifty yards radius. These instructions are certainly a little vague, but then this simple rondo does not come in for serious consideration by von Frisch. It is the second pattern of movement, the tail-waggling dance, that is so full of meaning.

Von Frisch discovered to his astonishment that if he moved the food farther away the dance became more complicated as the distance approached one hundred yards. Beyond a hundred yards its pattern had changed completely, and it acquired the form of the tail-waggling dance.

The bee first runs in a half-circle, then back along the diameter to the starting point. She then completes the circle by running in a half-circle in the opposite direction. Actually she describes a figure of eight and while treading her measure waggles her body from side to side.

As the bee dances on the vertical comb, she moves across it in some particular direction. There is nothing haphazard about the direction in which she moves, and if we can imagine her as drawing a line on a blackboard this line will form an angle of definite size with the vertical axis of the board, which, to get back to the hive, we can now imagine as a comb. This angle is the same size as that formed by the line between the sun and the hive, and the line between the hive and the food.

Thus the bee has given the direction in which the other workers are to fly by giving them a kind of compass. If the line she has danced along is to the right of the vertical axis of the comb then the bees are to fly at a corresponding angle to the right of the sun. No matter how the food is placed in relation to the position of the sun and the hive, the bee reproduces the angle on the comb.

Inside the hive the bee performs her dances in darkness. Critics of von Frisch's discoveries have not been slow to seize on this point and to enquire how it is that the bees are able to appreciate the size of an angle in complete darkness and in the very crowded conditions of the hive. Whether these are strong objections or not it is not easy to decide. Even if some of us may be reluctant to believe wholeheartedly in von Frisch's dancing bees, we must accept his interpretation of their curious behaviour until we are able to put forward a more plausible explanation. One thing stands out very clearly: as a consequence of the dance a certain excitement is communicated to the bees that causes them to leave the hive and seek out the source of food.

The language of the bees operates when it becomes necessary for them to take the fullest advantage of a supply of food by gathering it quickly while it lasts. It seems that the bees speak loudest, or rather dance best, when their crops are filled with a syrup or nectar having a high concentration of sugar. If the concentration of sugar falls, the bees lose interest in telling their fellows about it.

It is not only about where food is to be obtained that the bees pass on information to each other. There is at least one condition in their lives when they do not need the stimulus of a cropful of syrup in order to convey a message. I have already said something about swarming and described how scouting bees find a home suitable for a clustered swarm to which the bees all eventually move. How do they find their way? The swarm moves as a whole, and even von Frisch, I imagine, would not go so far as to say that detailed instructions about the angle that the line of flight is to make with the sun will have been passed to every bee in the swarm, which may contain as many as twenty thousand of them. And yet it is clear that some force holds the flying bees together. They move off with a purposefulness that leaves no room for doubt that whatever kind of stimulus this is, it affects all individuals of the swarm equally strongly.

In bumble-bees there is no equivalent of the colonizing movements of the honey-bee; they never move as a body, but work as individuals. Since conditions, however, within a nest are the same for all of them they produce the same responses and thus show a corporate activity which is similar to that of the honey-bee.

When I kept colonies of bumble-bees I was often obliged to feed them in order to keep them alive. Often the disturbance of digging out the nest and setting it up in a new home would lead to the loss of a certain number of the workers, and this, followed perhaps by a spell of particularly bad weather, would bring the little family to the verge of disaster. The remedy was simple. I used to place a small tin lid filled with sugar syrup within a few feet of the nest and train one or two workers to come to it. The worker to be trained was one that had become fully accustomed to the new nest site. I caught such a bee and placed it where it could reach the syrup. She filled her crop, hovered over the tin lid in order to memorize its exact position, and then flew back home. The bee would return to the syrup over and over again, but she never brought a companion with her. She was inarticulate, and whatever excitement she felt she was obliged to keep to herself.

I frequently kept my bumble-bee nests in large flower-pots, using them right way up. Their conical shape suited very well the growth of a bumble-bee's nest. It was easy to slip a piece of wood or slate over the top to keep it dark and cosy. To provide an entrance I chipped a hole in the side of the pot near the bottom and built on to it, by means of soft clay, a tunnel or covered way that went half-way round the side of the pot. Returning bumble-bees thus entered their nest through a three- or four-inch tunnel. It was perhaps unnecessary for me to try to make for the bees a home that resembled a little the kind of dwelling they occupied in nature, but it gave me the chance to watch them pause for a couple of seconds at the entrance which I deliberately made small enough to prevent their disappearing into it too quickly. I liked to see their heavy loads of brightly-coloured pollen, and I noticed how often a bee, returning with a crop full of nectar and landing half an inch short of the hole, would make a curious little sound

—which I always like to think was a cry of pleasure—as she found the entrance and hurried through it.

There is a big difference between the amount of food needed by a colony of *Bombus* and a colony of *Apis*. The bumble-bee nest may take some three months to build up a population of a few hundred individuals. The amount of nectar and pollen consumed by the colony is relatively small and can be collected over a long period. Moreover, it can be gathered near at hand and quite often from plants not favoured by the ubiquitous honey-bee. The lupins provide pollen for the yellow striped workers of *Bombus terrestris* and *Bombus lucorum*, and no bed of delphiniums is left unattended for long by the workers of another striped bumble-bee, *Bombus hortorum*, whose long tongue can just reach the nectar at the base of the stocking-shaped corolla of the flowers. No need for a special language among the bumble-bees, for their continued existence, unlike that of *Apis*, is not geared to an ability to store a large quantity of honey. *Apis* must feed on its stores of food during the winter in order to live through to the spring. But the future of the bumble-bee is locked within a queen that passes at least six months of her life in a death-like winter sleep.

I was quite young when I first became fond of bumble-bees. Later on I was not able to resist the charms of the fiercer wasps. For many years I kept nests of these much-maligned insects in large glass-fronted boxes on either side of my bedroom window. Three floors up they were a menace to no one, but I have no doubt they enjoyed themselves with the neighbours' fruit.

If you share a room with several thousand wasps, even though you have, as it were, your own cubicles, you cannot fail to learn something about their ways. And one thing I discovered was that worker wasps were as powerless to pass on information about a source of food as bumble-bees.

The wasp hunts alone, striking at small dark objects on flowers, stems or leaves until at last it clasps a hapless fly in its strong legs. This kind of hunting must be an individual affair, and it would be silly to suppose that a wasp, if she had made a series of particularly successful trips in search of prey, would return home and tell her companions that she had found a spot where the hunting was good. Even when wasps crowd around a discarded treacle tin on a rubbish dump, I do not think that a secret language has brought them there. Chance and a good sense of smell have been their twin sources of help.

It is because the honey-bee is able to communicate with its fellows by means of the dances that it has come to occupy the highest position among insects that have any claim to intelligence at all. Not that the dance need be taken as evidence of intelligence as we use the word in describing our own behaviour. It can be explained as an extremely sensitive but automatic response of a nervous system of a much more complex type than we expect to find in insects. The interpretation of the dance is no less wonderful for all that.

Chapter Nineteen

THE SENSES OF BEES

THE question most frequently asked of anyone who keeps bees is: "Do you often get stung?" Now any beekeeper knows that you cannot keep bees without sometimes getting stung. How often you will be the target of an angry bee depends on many things: the innate temperament of a particular colony of bees, the time of the year, and especially the way in which you open the hive and handle the combs. I like to think that my bees and I manage, on the whole, to avoid really serious clashes.

This is what I tell any questioner. But he usually has his own ideas on the subject of stinging, and explains away my comparative freedom from stings by saying that the bees, like other domestic animals that recognize their master, have got to know me. Now whatever senses a bee may possess it certainly lacks the ability to note and remember the very complicated collection of features that make up a human individual. If the bees do not pour forth in fury every time the hive is opened, it is not because they recognize the touch of their own benevolent keeper but because he, from his experience of the ways of bees, avoids the bumping and jarring, the pinching and crushing, and the rapid, jerky movements that are to them like red rags to a bull.

I think we can safely say that bees do not recognize the beekeeper. It is possible that they might smell him and, finding his odour objectionable, attack him with all their might. But this is a different matter, for no doubt at all exists that bees—honey-bees that is, for little is known about the others—have a very keen sense of smell. This has been proved experimentally. It is a subject to which Dr. von Frisch, whose name is especially associated with the remarkable dances of the bees, has given a great deal of thought and attention.

The honey-bee's sense of smell receives its stimulation through the antennae, or feelers. The worker's antenna is composed of twelve segments, but it is only the last eight that she uses for distinguishing different smells. On these segments are small areas where the tough horny skin is thin—thin enough to allow particles of an odoriferous substance to enter and stimulate the nerve-ending which lies just beneath the surface. The experiments of von Frisch have shown that bees are just about as good at distinguishing different smells as we are.

The sense of smell is vitally important to the honey-bee. *It helps them to distinguish friend from foe.* You can see the guards at the entrance of a hive rush at and try to seize the strange bee from a neighbouring colony that seeks the chance to slip in and steal the honey. What is curious is that each colony of bees has its own particular scent, a chemical password that enables all members of the community to work together in peace and harmony. Over and above this common scent that neutralizes each individual worker's power to excite a sister worker in any way disadvantageous to the well-being of the colony, there exists that subtle emanation that comes from their queen. It diffuses continuously, or so it seems, throughout the entire colony, so that if the queen is removed the bees become aware of her absence, and for a time show every sign of being distressed and disorganized. You cannot now restore order and contentment by thrusting another queen upon them, for though she may have the royal odour she will carry also the scent of the bees from whom she has been taken. The chances are that she will be attacked immediately, the bees closing in upon her so that she comes to be locked tightly within a small knot of them, perhaps the size of a walnut. She is soon stung to death and her body cast out. But shut the queen in a little cage where no alien worker can reach her and place her then among the queenless bees. Gradually she will acquire the scent of her new subjects and when, at the discretion of the beekeeper, or through the delayed releasing action of the cage, she is finally set free among them, she is almost sure to receive a happy welcome.

The honey-bee's sense of smell plays a big part in the economy of the hive. It also helps to co-ordinate the activities of the bees during the period when they function as a swarm and are temporarily without a settled home. How is it that bees of a swarm manage to keep together, flying often quite long distances and at the end of the journey still maintaining their cohesion as a colony? A part of the answer—perhaps all of it—lies in the scent organ that is concealed between two of the ring-like segments at the tail end of the bee's body, and known as the Nassonoff gland. Actually there are a large number of gland cells, each of which discharges its secretion into a common pocket. This scent gland is, in my opinion, one of the most important organs possessed by the bee. By exposing it and diffusing its scent through a rapid vibration of the wings, the worker bee is able to call other bees to it, thereby establishing a means of communication to which all members of a particular colony quickly respond. I can best tell you how useful this gland is to the bees—and sometimes to beekeepers also—by relating the story of what happened to a swarm of bees that suddenly began to pour out from one of my hives on a hot July morning.

It was a Sunday, sultry and overcast, not quite the sort of day the honey-bee normally chooses for swarming. Incidentally there is an old belief, naïve and charming, that bees swarm on a Sunday because this is the one day of the week when there are people about with time enough on their hands to notice the event and take care of the wayward bees.

When I saw my bees streaming crazily from the hive I was afraid they would settle at the top of the big cedar tree that dominates my garden. Here, I knew, they would be lost to me unless, by chance, the queen was unable to join them. If, when they eventually settled, they missed her they would all return to the hive. There was still a chance that she had not yet left, so I crouched by the hive entrance with a little box in my hand, watching the bees pouring out and hoping that I was in time. I was. Suddenly the queen appeared, a little frightened and bewildered perhaps, but unable to resist the force that drove her out. In a moment she was in my box and I had the smug feeling of having outwitted the bees. By this time the stream of rushing bees had become a mere trickle, and there was nothing to show that some fifteen thousand of them had left the hive in the space of a few minutes.

The swarming bees were whirling around the top of the cedar tree and beginning to form a cluster on one of its highest branches. It was now that I put into practice an idea that I felt should work. If it did I should get my swarm without their having to return queenless to the hive. The plan was simple though I do not claim any value for it in practical beekeeping.

I let the queen run into a little cylindrical cage made of perforated zinc and shut her in with a cork. Next I fixed this cage to an old blackened and fragrant honeycomb and raised them both up on the end of a long clothes prop. Then I held my prop, or rather waved it gently about, among the lower branches of the cedar tree, where the bees were still flying, and hoped that they would find it. But neither the fragrance of the honeycomb, usually so attractive to bees, nor the near presence of the queen mother herself, was able to attract a single bee. Discouraged, I ceased to press my bait on the reluctant bees and instead placed the prop against a step-ladder that had been stood in readiness beneath the tree.

And then, suddenly, a bee settled on the cage and immediately began to fan its wings rapidly, while at the same time exposing, as a white spot, the scent gland at the end of its abdomen. In a moment it was joined by a second bee that at once added her contribution of scent by repeating the wing-fanning motion of the first bee. What now followed could be called a landslide. Bees settled in ever-increasing numbers, covering the cage and the comb until, after a few minutes, the whole swarm came swirling down like a stream of smoke from the top of the tree to join their sisters and their queen on the end of the clothes prop.

Before the cage was completely submerged beneath the growing cluster of bees I removed it, took out the cork and allowed the queen to run freely on to the swarm.

So much of the bee's life is spent amidst brightly-coloured flowers that it would be surprising if these colours had no meaning for it. The experiments of von Frisch have shown us that the honey-bee has a colour sense, though it is by no means as sharp as that of a normal human being. It can distinguish between black and white, and can recognize blue and yellow. How this result has been proved is a little complicated and depends on training the bees to visit food on coloured cards and changing these cards for others or altering their position. By appealing to the bee's sense of taste—its love of sweetness—the extent and limits of its colour vision have been detected.

Orange, green and yellow appear pretty much the same to the honey-bee, though when confronted with a choice of these colours it seems to be attracted, under experimental conditions, to yellow, even if previously trained to visit orange. Bees can distinguish blue, though they are a little bothered if expected to know it from purple or violet.

If the bee's colour sense falls far behind ours in distinguishing as many colours as we can make out, it goes one better in being able to perceive the ultra-violet in the sunlight. This, of course, is invisible to us. The redness of flowers conveys nothing to the honey-bee, for it is red-blind. That is to say, it is blind as far as scarlet-red is concerned; red flowers that contain a certain amount of blue in the red are recognized by the bees. How is it then that the honey-bee will visit the scarlet-red poppies? Von Frisch says it is because the red in the bright poppies reflects the ultra-violet light from the sun so that they are given a colour that is clearly visible to the bees.

As well as being able to respond to different colours and different odours, bees have also a sense of taste. They are, as everyone knows, especially fond of sweetness; sucrose, the sugar of the beet and the sugar cane, makes a particularly strong appeal to them. When little dishes of syrup are offered to them, each containing a different concentration of sugar, they seem happiest where the drink is sweetest. The smallest amount of sugar they will tolerate in a solution depends on whether they happen to be very hungry or whether they have discovered a sweeter solution elsewhere. When plenty of flowers are about the bees visit those whose nectar is richest in sugars. But in times of scarcity they are much less fastidious. Nevertheless, unless threatened with starvation they will refuse water that contains less than 5 per cent of sugar.

So far we have seen that the honey-bee has a sense of smell, a sense of taste and the ability to distinguish between certain colours. Perhaps this is what we ought to expect, for the bee spends much of its time in a flower world of bright colours, fragrant scents and nectars that are far from being equally sweet.

The honey-bee lives also in a world of noise. Many of us are familiar with the high-pitched buzz of an angry bee, and most of us, at some time or another, have listened to the soothing hum of bees as they work on a still summer's day among the blossoms of the lime trees. And even when they are not flying, they are far from silent. You have only to put your ear against a hive to find out that the inmates are all the time uttering strange and varied noises.

Now it seems that the worker bees make these sounds by vibrating their wings at different speeds, and it is the rate or frequency of vibration that produces the different qualities of sound that we humans can hear.

A common belief exists that the medley of sounds coming from the bees as they go about their business is a kind of speech whereby they communicate with one another. But phantasy and imagination have added so much to what is believed about the language of the bees that no harm is done, I think, if the subject is looked upon as still in need of a bit of straightening out.

What we would all like to know about these bee sounds is how the bees actually perceive or become aware of them. A few years ago, in trying to find an answer to this question, I came across a scientific work written by a Dr. Åke Hansson and published by the University of Lund in Sweden. It is all about the different sounds made by honey-bees and their ability to perceive them.

By setting up a great many careful experiments, Hansson discovered that the bees in the hive are affected by sounds that fall within a certain range of frequency. But except that they reacted more feebly to the highest and the lowest pitches within the range of these sounds, they are affected by them all in much the same way. Thus the bees, it seems, are unable to distinguish between different sounds; the quality of sound, its pitch or tone, means nothing to them. And if they react to different sounds in the hive, it is because, so Hansson's experiments have suggested to him, they are extremely sensitive to vibrations that reach them through the material on which they happen to be standing or moving.

Among country folk you will still find many who believe that bees talk to each other in much the same way as we do. This idea that they could hear and understand was shown in the old custom—that may still not be dead for all I know—of telling the bees when death or disaster came to the beekeeper's family. At swarming time especially their language became potent with age-old mystery. The confusion of sounds made by the swarming bees blended to make a music more powerful than mere speech; it was a wild song that lured the more cautious ones, those unwilling to forsake the comfortable skep beneath the ancient apple tree, to cast off their responsibilities and join their fellows in a brief ecstasy of abandon. Beekeepers of the past believed in the magic of the bees' music and its call to freedom and revelry. Why not, after all? The ways of the bees were as inscrutable as those of Providence and caused as little surprise. It was only when they threatened the honey crop by engaging in strange aerial antics that sometimes ended in their making for the woods, to be lost for ever, that it was thought prudent to take whatever action might keep the bees at home. If their song could be drowned, its spell would be broken. That is why it used to be a common practice to set up a rival din as soon as the bees began to swarm by beating any old metal pan that happened to be handy.

The discord of sound left the bees unmoved, for it seems

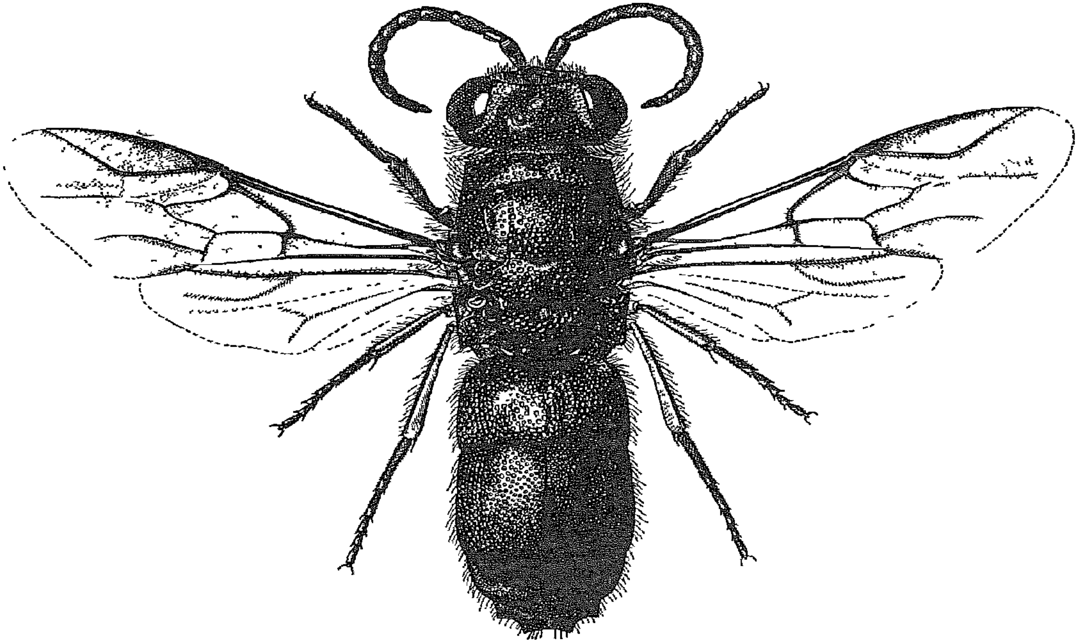


Fig. 15

A ruby-tailed wasp, very common in Britain, that lays its eggs in the nests of solitary bees: *Chrysis ignita* (see page 139)

that while they are flying they do not perceive sounds in any way. Hansson analysed the hum of swarming bees but he found nothing unusual about it. It is loud to us simply because many bees contribute to it, like the chatter in a theatre before the lights go out. By fixing a microphone on the end of a long pole and holding it in the midst of a flying swarm, Hansson was able to register on a delicate recording instrument the various sounds made by bees that flew close enough to the microphone. When he came to analyse his figures he found that they fell into two groups. One group showed a range of low rates of wing vibration, while the other showed a range of higher rates of vibration. The low frequency corresponded to the flight of the drones and the higher to that of the workers.

The average frequency for the workers was 237 wing beats per second. This is rather low for a worker, but corresponds, as Hansson discovered when he compared the figure with the results of some of his earlier experiments, with the rate at which a bee vibrates its wing when loaded with a full crop of honey. This is actually the condition of the bees that make up a swarm. Before setting out on the great adventure they feel an urge to drink heavily at the honey cells.

At swarming time a curious sound can often be heard coming from the hives. That is, from a hive whose old queen has already left with a swarm and whose bees are still in the mood to send out further swarms. Actually it seems that two distinctly different sounds can be heard; they are made by queen bees, and together are known as the 'piping of the queen'. The circumstances under which queens will pipe are usually these: some days after a swarm leaves the hive, normally six or seven, young virgin queens are ready to leave their cells so that the colony shall once more have a queen to give point and purpose to its labours.

In a previous chapter I described how these young queens are all fired with an impulse to seek out and destroy each other. But it is evidently not in the natural scheme of things that the virgins, so carefully nurtured and brought to their royal prime just when the colony is richest both in stores of food and numbers of bees, should be allowed to engage in reckless and wasteful slaughter of each other. Already we know that the first of these young queens will leave with swarms, the numbers of swarms, or 'casts' as beekeepers call them, depending on various factors, but chiefly, I think, on the number of worker bees that are surplus to the immediate requirements of the colony.

As soon as the first virgin emerges she will begin to utter a challenging pipe; it is convenient to call it a challenging pipe, even at the risk of making the queen sound much too human. It sounds rather like a series of 'zee . . . ee . . . ee . . . eeps'. And it is answered by the virgins still in their cells with a sound that resembles a 'quahk, quahk'. The pipe of a queen running free in the hive has a higher frequency than that of a queen still confined to her waxen cell. Hansson says it varies from 400 to 500 vibrations a second. The answering call has a lower frequency that does not rise above 370 vibrations a second.

So long as the challenging call continues to be answered by the muffled 'quahk' of the young queen in a cell, the issue of a swarm is likely. When the virgin has left another will venture forth from her cell to take her place. She, too, will pipe, but now that she is free her piping becomes more shrill and reaches the higher frequencies.

As to how these royal sounds are made there is still some doubt. Hansson considers they are produced by the vibration of the complicated set of horny plates and muscles at the base of the wing.

Chapter Twenty

THE FLIGHT OF BEES

BEES, like their relatives the wasps and the ants, have an extremely well-developed faculty for returning to the spot that happens to be their home or nest. It is predominately the female that shows this skill. The male, since he is not troubled with the responsibilities of providing for a family, is not tied to a home. Though his flight territory *may be restricted, he is kept within it by environmental* forces different from those that govern the movements of his mate. There is one obvious exception, though there may be others. The drone honey-bee always returns to the hive in which he was born. He takes his flights in the sunshine, seeking his pleasures high in the air. But fate has been unkind to him, for he has been deprived of the independence that belongs, as a simple right, to the males of the solitary bees and the bumble-bees. They at least can feed from the flowers, but no one has ever seen the drone of *Apis* taking refreshment in this way. For his meals he must return home, or starve.

To see bees leaving and returning to a hive is such a commonplace event that it arouses little interest. But go to a spot where the solitary bees are nesting, perhaps a rough path made hard as rock by rain and constant treading, and see some of the *Halictus* bees at their work. A minute insect, a bare quarter of an inch long, her back legs bright yellow with pollen, arrives as though from nowhere and flits persistently over a spot no more than two inches square.

The mouth of her burrow has been accidentally hidden by dust or sand. But whether or not there is some landmark, unobservable to us, she alights where we see nothing and with a few flicks of her feet has disappeared into a hole.

This is one end of the bee's journey. She has recognized her front door by its marks or its odour. But what about the other part of the journey—the trip between the flowers and the burrow? Once so small a creature is launched in the air we cannot follow her flight and can only make guesses about the kind of sense impressions that are influencing her course. Does she make her way by means of landmarks, perceived and registered in her brain as a pattern of particular shape?

Fabre thought that bees had some mysterious sense of direction, a faculty not to be explained, but recognizable by its effects. He carried out a large number of experiments with certain solitary bees—the mason bees whose habits have already been described. He took them as far as two miles from their nests and released them. But they were not all equally fortunate in being guided home, for at intervals varying from five minutes to five hours, only 47 out of 144 ever did get back.

With the passage of time there has grown an increasingly stubborn refusal to sit back and be deliciously mystified when no simple explanation can be found for some observed fact of nature. It is a little too easy to postulate some uncanny sixth sense. We certainly do not know how the earth looks to a bee as it flies through the air. It has eyes and through them it is receiving impressions. But its environment is wider than that of an insect that crawls on the ground, and is more deeply permeated with the influence of the light of the sun in all its varying intensity and direction.

Since the time of Fabre other observers have been intrigued to find out how a bee can soar into the air, lose itself in space, and yet, its particular errand carried out, return without difficulty to its nest.

At Royston, in Hertfordshire, I used frequently to find the nests of a bumble-bee known as *Bombus helferanus*. They were dome-shaped, built up of small fragments of dry grass and occurred at the roots of the long grass that covered some stretches of the downs. I never ceased to wonder how it was that the bees found their way home on days when the wind blew continuously and covered the slopes on which their nests were hidden with a sameness of waving grass. Yet landmarks must have been present which the bees could detect, for I used to watch them, flying low over the ground and making steadily, though not without a certain amount of deviation, for the exact spot where their nest was.

Ants, bees and wasps appear to find their way home by a combination of sight and scent. In ants it is probable that a scent trail plays the greater part in guiding them, though their perception of the direction of the sun's rays may help them also.

For the bees and wasps, sight is probably the means by which they find their way back to their nests. To appreciate how important it is to them one needs only to watch a bumble-bee or a social wasp taking its first flight. This is a very important stage in the young worker's life, for should it fail to find its way home its loss will affect the development of its colony, especially if it belongs to the first batch of workers that take over the duties previously carried out by the queen alone.

In my experience the homing bumble-bee is never away for more than a few minutes on its first flight, and on its return always experiences a certain amount of difficulty. Let me explain more clearly what I mean. I have already described how I kept colonies of bumble-bees in flower-pots, and how I arranged things so that the bees entered their nests through a narrow tunnel made of clay. The entrance hole was a bare half-inch in diameter and faced the open window, the pot being stood just inside on a bench. During the morning newly-emerged workers, about two days old, would take their first flight in preparation for becoming foragers. One would appear at the mouth of the little hole, turn round and face it and then, with great precision of movement, rise on its wings just above the surface. At first it hovered within an inch or so of the entrance, but gradually it swung from side to side in ever-widening half-circles, all the time facing the site of the nest, until finally it swept out of the window to continue its circling flight until I could follow it no more.

Now all this time the bee was receiving an impression through its eyes, a kind of mosaic pattern which was being registered in its brain as a memory. In this pattern, one small *spot, the actual nest entrance*, had a *special meaning for* the bee and could be found again only if the surrounding landmarks were carefully observed and remembered.

If I disturbed the bee at this critical time, especially when it was hovering close to the nest entrance, it would fly off in fright and not return. Sometimes, if not too badly disturbed, it would come back and fly around the nest site, though in the end I was always obliged to catch it and put it back in the nest.

Even if all goes well, the return from the first flight is always hesitant, and this becomes more and more marked as the bee approaches the actual entrance. The second departure from the nest is less cautious, and after a few flights the forager leaves and returns with unerring directness.

Young wasps and hornets seem to be just as dependent on sight for finding their way home as bumble-bees. On the numerous occasions when I have observed them leaving the nest for the first time, I have been struck by the care with which they appear to note every detail of their surroundings.

With the honey-bee the successful return from a first flight depends, perhaps, not only on sight but on scent as well. Normally, the young bees do not leave their hive singly; hundreds of them leave at the same time, flying all around the hive as though they were swarming. Such flights are best seen if there is a sudden burst of sunshine after a succession of dull days. The young bees rush out of the hive in great excitement, but if you watch them as they crawl out on to the alighting-board you will notice that they always face the actual entrance before flying up. They move in a kind of swaying motion from side to side and then suddenly rise up.

Beekeepers refer to this mass exodus of young bees as a play flight. I doubt, though, if there is much play about it. It is a necessary phase in the bee's life, helping it to learn the location of its hive. The actual return to the hive entrance is somewhat different from what I have described for bumble-bees and wasps. As the young bees alight they do not run straight in, but remain still for a moment, fanning their wings and exposing the scent gland at the end of the body. Other young bees settle near their fanning sister until there is a great throng of them, moving slowly in through the hive opening. I have described elsewhere how important the scent gland is in controlling the movements of honey-bees as a corporate body. The part it plays now in guiding the young bees home is another example of its uses.

How fast do bees fly on their journeys? Enthusiasts have put the speed of the honey-bee at 120 miles an hour, but no experiment has ever given authority to this fantastic figure. When the matter is really put to the test, it turns out the bee does not fly faster than twenty-five miles an hour. When fully loaded she cruises along comfortably at around fifteen miles an hour.

If a bee is disturbed as it works among the flowers it appears to dart off in a flash. At once there is created an illusion of great speed that is enhanced because of the insect's small size. The human eye finds it almost impossible to follow a small moving object at close range even if it travels comparatively slowly. A bee that shot off into the air at fifteen miles an hour would certainly appear to be flying with lightning swiftness.

Almost nothing is known about the powers of flight of the thousands of relatives of the honey-bee. If there is much variation in the speeds they are able to reach it is not suggested by their wings. For these tend to be monotonously uniform in appearance. Variations in their shape are so small as to be hardly noticeable, and throughout the entire family of bees there is pretty much the same proportion between the size of the wings and that of the body they have to carry.

If we turn to other insects we see a difference. Consider the moths for a moment. There are the Sphingids, or Hawk-moths, narrow winged with relatively large streamlined bodies—exquisite examples of an emphasis put on speed in flight. At the other end of the scale there is the huge Atlas-moth. It is only one of many different kinds of Saturniid moths, all of them lovely creatures from the Emperor-moth of the British moorlands to the Moon-moths of the tropics. Their characteristic features are large, broad wings and a small body. Their heavy flapping flight is slow and clumsy in comparison with the swiftness of the Hawk-moths.

If we try to find some biological significance in the narrow wings of the bees, it is hard to avoid the conclusion that their design shows a delicate compromise between two conflicting requirements: one, that they should give the bee speed, and two, that they should hinder it as little as possible while it attends to its business in the nest.

The need to move fast between nest and foraging ground is vitally important to every female bee. In temperate regions at any rate dull weather may keep her home for long periods. And since there is a heavy programme of work to get through, she must be off with all speed, as soon as there is a spell of sunshine, to gather her loads of nectar and pollen. Back home, where she has to move backwards as well as forwards in a narrow tunnel, whether it be in the ground or in wood, it is obvious that a pair of wings, designed to produce maximum speed in flight, might be a hindrance to a bee crawling along a passage just wide enough to admit her body.

Chapter Twenty-one

BEES AND FLOWERS

We all know what bees get from flowers, but we are not always so sure, perhaps, whether the flowers receive anything in exchange for the nectar and pollen that they give so freely. Actually they benefit very much from the visits of the bees and are well repaid for all the services they render. It is not possible, however, to see the full meaning of this mutual aid unless something is known of the way in which plants reproduce themselves.

In order that a flower may set its seeds, it must first of all be pollinated. This is not the same as being fertilized. The male sexual cell is concealed within the pollen grain. Somehow it must find its way to the sticky surface of the female organ, or stigma. If it does eventually arrive, the pollen grain begins to grow, putting out a thin pollen tube that penetrates the tissue of the stigma, and finally, having passed down through the style, enters one of the ovules. Here male and female sexual cells unite, their nuclei fuse and true fertilization is accomplished.

Now, many plants rely on the wind to pollinate them. Leaving so much to chance they need to produce copious amounts of pollen of a kind that is readily wind-borne. Such plants are not, as a rule, attractive to insects. They can get on very well without them. It is true that the ubiquitous honey-bee will sometimes visit the catkins of the hazel on warm February days, but in taking the pollen it brings no benefit to the plant. For the hazel does not combine male and female elements in a single flower. The female flowers grow separately from the male flowers or catkins, and having no attractions to offer the bee are passed over. Another thing about these plants that rely on the wind to aid them in their reproduction is that they do not have flowers that delight the eye. I doubt whether anyone noticed beauty in the inflorescence of the stinging nettle, or was moved to eloquence by the dingy flower spikes of the common plantain.

Not all of us appreciate that the form, colour and scent of flowers are not Nature's gift to man but cunning devices, blandishments and drugs to attract the insect legions. And when the insects come they are bribed by pollen and nectar to linger among the flowers, passing from plant to plant, and as they go, spilling and scattering the pollen grains until, unwittingly, they have achieved the cross pollination essential to many plants.

These plants that depend on insects for the successful union of their sexual cells do not produce pollen so lavishly as the plants that rely on the wind. Perhaps they achieve pollination by surer means. At any rate they have, in the course of their long development, evolved little tricks to make doubly sure that they are properly served. Their pollen grains are often slightly sticky or have a rough coat so that they get stuck to the legs of visiting insects or become entangled, like burrs, among the hairs with which their guests are often covered. Insects like to eat the pollen grains; they are rich in proteins and make a nourishing diet. It seems not to matter how much pollen is eaten for the plant always provides far more than it actually needs.

Bees are not the only pollinators. Moths, butterflies, two-winged flies and small beetles are attracted by the nectar and pollen of plants and play their part in transferring the pollen grains from stamen to stigma. The bees do, of course, occupy rather a special position in this relationship between flower and insect. They cannot exist where there are no flowers, whether these be the blossoms of the eucalyptus trees in Australia or the modest trefoils that bloom on the hillsides in Surrey.

No insect exploits the flower more completely than the bee; she takes away a whole load of pollen for every grain that she accidentally transfers to a stigma. Hers is a big return for a small service, you may say. Yet we see the proof that the service is rendered in full by the heavy set of fruits and seeds when the bees have been able to work freely among the blossoms at flowering time.

The honey-bee, as well as being an excellent pollinator, performs an extra service by gathering the nectar from millions of flower corollas and making it available to us in the form of honey. In serving us twice over it deserves our fullest respect. I hope, therefore, that I shall not be accused of belittling a most admirable insect, if I say that the honey-bee owes something of its importance as a pollinator to the absence of competitors. The solitary bees and the bumble-bees are being gradually ousted. Nesting, as most of them do, in the ground, they are losing the quiet tracts of land where they bred undisturbed for countless generations and carried out the task of pollinating the native flora around them. Their homes are not respected by the plough and the tractor, which, by an ironical twist of fate, so often prepare the soil for a crop that needs the help of the very insects they destroy.

We are all familiar nowadays with many important matters concerning the growing of plants. The suitability of the soil, the respective merits of compost and artificial fertilizers, the struggle against insect pests—all these you can hear discussed with much enthusiasm in trains, country pubs and over the garden fence. Of pollination you hear less. The work of the beneficial insects is taken for granted. Have you ever noticed the small active workers of the Early Spring bumble-bee, *Bombus pratorum*, that visit the raspberry blossoms in May? They turn up each year without fail at the same time, and in company with the honey-bees pollinate the flowers that become the raspberries you pick in July.

Should the plant become separated from its insect pollinators it loses its fruitfulness. When New Zealanders first started to grow red clover they found to their dismay that the plants did not set their seed. The soil was right, the climate perfect and the clover bloomed profusely. But when the flowers withered and died there was no good seed left in their place. Investigations were made in Europe and it soon became clear that the long-tongued bumble-bees that foraged so busily in the clover fields were actually rendering the plants an essential service. New Zealand had no bumble-bees, and there were no native bees with tongue long enough to take an interest in the alien crop. And so it came about that queen bumble-bees were carried thousands of miles by ship to do for the red clover in New Zealand what they did so efficiently and so unobtrusively in Europe.

Red clover belongs to the sweet-pea family, known to botanists as the *Leguminosae*. It is by no means the only clover that is grown as a crop, for the clovers generally are valuable plants. Nearly all of them are unable to set their seed with their own pollen, and being self-sterile are completely dependent on insects for cross-pollination. They need the help of the bees. In return they provide, often capriciously in Great Britain it must be admitted, a nectar that the bees transform into one of the most delicious of all honeys.

And so it is with most of the varieties of fruit that we eat. The sweetest, crispest, juiciest apple there is, Cox's Orange

Pippin, comes from a blossom that could never develop a fruit unless it received pollen from some other variety of apple. The pollen must be brought to the flower and there is no agent that can do the carrying better than the honey-bee. In fact the honey-bee is such an efficient pollinator of fruit blossom that fruit growers hire hives of bees so that at blossoming time the orchards are occupied by an army of pollinators.

All this does not mean that the only thing necessary to obtain fruit is to put a hive of bees under the tree. The bees may do their job too well; they may over-pollinate. Some fruit growers are not at all keen to have hives of bees actually in their orchards. "Too much fruit is set," they will tell you, "and we have to spend money to get it thinned." These men prefer to rely on the fewer numbers of honey-bees that will reach their orchards anyway, for it would be hard indeed for any orchard to be situated where no bees could find it at blossoming time. Again, you cannot assemble bees for the purpose of pollinating a crop if there are other plants near it that are more attractive to the bees. If they could find nectar that was more accessible or tasted sweeter, they would forsake the blossoms offered them and please themselves.

James Hambleton in America has made a special study of the problems connected with bees and pollination. He has many things to say about the way in which plants compete for the attention of the bees. For instance, there is the story of alfalfa, or lucerne, as we call it. Here is a plant that thrusts its roots deep into the soil and can withstand conditions of drought better than others growing around it. By getting water when shallow-rooted plants are dying of thirst, it can still offer nectar to the bees. So that a good crop of seeds is assured even though the lucerne plants are stunted through having had less water than they need for optimum growth. But if conditions have favoured all plants equally and the competitors of the lucerne have produced their flowers in profusion, then the shallow-rooting plants have an advantage because in offering the bees a sweeter nectar they keep them away from the less attractive lucerne.

The honey-bee is kept in almost every part of the world. It ranges far and wide, and will visit almost any kind of flower whose nectaries it can reach or that can satisfy its demands for pollen. As an instrument of pollination it has one peculiar advantage. Since it is kept in a hive that can be moved without difficulty, the honey-bee can be transported, with no more than passing inconvenience to itself, five miles or five hundred. It can be assembled in hundreds of thousands just where it may be wanted. As soon as the bees are released from their hives after a long journey they make an orientation flight to fix in their memory the new location of their home. Within a few hours they have adapted themselves to their changed surroundings, and are contentedly foraging among plants they have perhaps never visited before.

The moving of hives from one part of the country to another is called migratory beekeeping. It is practised a lot in North America and Australia, but hardly at all in the British Isles because conditions do not make it worth while. But heather honey, the choice of the connoisseur so I have often been told, may be justly called a product of migratory beekeeping. The moors and the mountain slopes on which grow the ling and the heather that sometimes secrete their nectar so bountifully cannot support bee colonies at other times of the year. Until August the bees must gather their food from a wide variety of plants such as are not to be found on the poor soil of the heather country. They are taken to the heather so that they may gather a crop from that plant alone.

Since bees are dependent upon flowers, nectar and pollen must be readily accessible to them. It is in the interest of the plant that its pollen should be quickly transferred from one part of the flower to another, or from one blossom to another. The bee need go to no special trouble to find it; in fact it can hardly settle on a flower without getting the pollen grains stuck all over its hairy coat. The nectar is not quite so freely proffered; often it is concealed deep down in a corolla and can be reached only by a bee with a long tongue.

Although it is risky to generalize, there does seem to be a correlation between certain kinds of flowers and the types of bees that visit them. The Compositae, or daisy-like flowers in which numerous florets combine to form a single inflorescence, are visited by bees with short tongues. *Halictus, Andrena* and a host of other genera of solitary bees are the ones you will find on flowers of this kind. There would be no point in a female *Andrena*, or a honey-bee, visiting the nasturtium because its nectar—and there is a lot of it—is hidden far from their reach in a long tubular spur. It is only the bumble-bee called *Bombus hortorum* that can reach this particular nectar, at least in the gardens of Great Britain. Its tongue is so long that it can reach to the bottom of the spur.

Many bees seem to confine their attention to a few special plants, and unless these plants are about you will certainly not find their bee attendants in the neighbourhood. To give an example: there is a little bee in this country called *Heriades campanularum*, entirely black and barely a quarter of an inch long. As its name suggests, it is the bee of the campanulas, and wherever you find these flowers in the districts where the bee is known to occur you will certainly find the bees round them on sunny days in July.

Examine the same flowers in the evening and you will

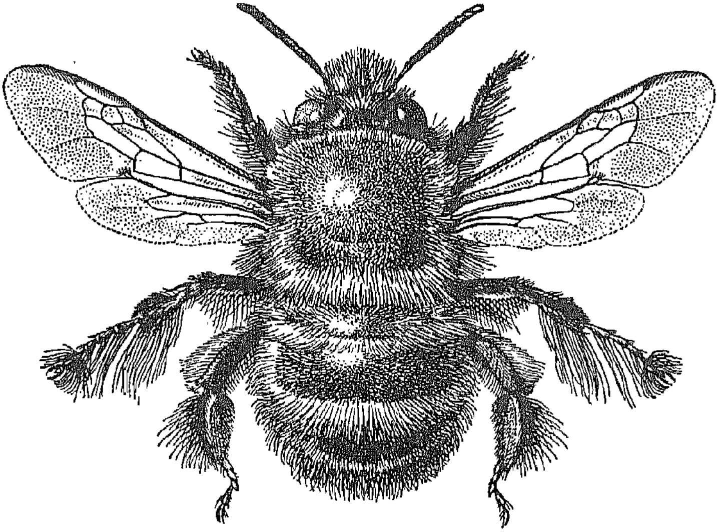


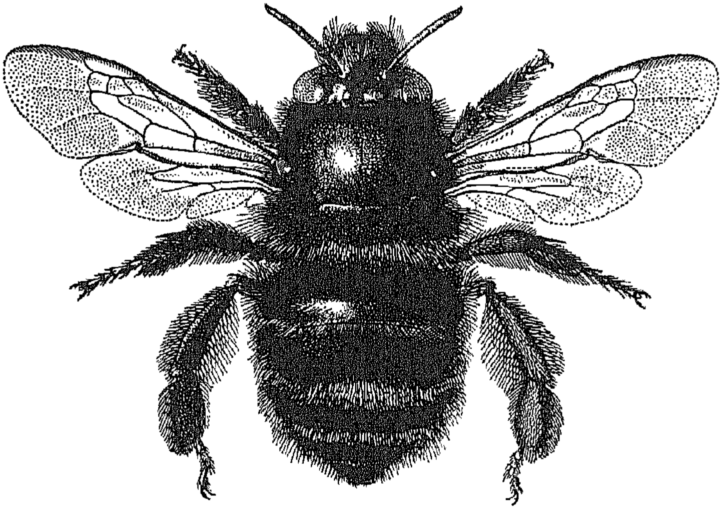
Fig. 16

The brown male

A solitary bee that nests in sand banks and old brick walls:

Anthophora pilipes

The black female (see page 153)



most likely find three or four of the little bees curled up in them roosting for the night. *Heriades* is known to visit other flowers, but for some unaccountable reason it is particularly fond of campanulas. And then there is *Macropis labiata*, larger than *Heriades campanularum*, more stoutly built and of decidedly elegant appearance. This solitary bee is something of a rarity in this country, but if you want to discover its haunts, you must find the places where the yellow loosestrife blooms, because *Macropis* has a special fondness for the flowers of this plant.

Some flowers make their nectar so inaccessible that it can only be reached by certain kinds of insects. The common antirrhinum, or snapdragon, is a good example. The main part of this flower is a hollow chamber closed by a kind of lip that presses up against a ridge formed by two dorsal petals. If you gently squeeze the sides of a flower between the thumb and finger you will force the lips apart and open its mouth. On the stem the flower sits with its mouth tightly closed except for a small cleft in the middle of the lower lip. An entry may be forced through the cleft, but this is no job for a delicate butterfly, or any of the many two-winged flies that visit flowers. It remains for the powerful bumble-bee to thrust in its hard pointed head, widen the gap and penetrate through to the nectary. Often the bee will disappear completely inside the flower so that the door closes behind it almost with a snap. But bumble-bees are sturdy insects and the temporary prisoner, once having cleared up the nectar, has no difficulty in forcing its way backwards out of the flower.

This is a legitimate way of obtaining the nectar because the bee, in order to get it, rubs its body against the pollen-bearing organs and carries the grains from one flower to another. In the process the need of the plant to be pollinated by an insect is properly met.

Flowers do not offer their nectar to all and sundry. It seems that in the evolution of the flowering plants and their insect visitors there has been a tendency for each to adapt itself to the needs of the other. This, at any rate, is what we observe where no agency, human or otherwise, has disturbed the association. The natural flora of any region can depend for its pollination on the insects that make up the natural fauna of the same region. But once the balance is upset all sorts of curious things may happen. Bees will sometimes learn to obtain nectar from flowers by illegitimate means, pilfering it in a way that brings no compensating advantage to the plant. Even the simplest acquaintance with the structure of entomophilous flowers shows quite clearly that an insect cannot reach the nectar without first of all brushing with some part of its body against the pollen-bearing anthers of the flower. Whether the plant is fertile with its own pollen, or needs the pollen from another plant, the *chances are that the visiting insect will transfer enough of* the pollen grains to ensure pollination. For such a service the droplet of nectar is a fair reward. But sometimes the bees will take the nectar, not by entering the flower and spilling the pollen, but by biting a hole in the base of the nectary and helping themselves to the sweets through the back door. Bumble-bees are often guilty of this. A friend of mine once told me how he had seen a bumble-bee working busily in a bed of broad beans, and how he had heard a distinct click as the bee snipped open the base of the flower with its sharp jaws in order to reach the nectar. This is by no means an isolated incident. The habit is commoner than might be supposed, and is not confined only to bumble-bees and beans. Phil Rau, from whose account of the carpenter bees in Virginia I have already borrowed, tells how the same bees will rip open the nectary of a flower called *Diervilla florida.* Apparently this particular carpenter bee has been known to damage the flowers of six other plants in the same manner. The interesting thing about its behaviour is that with one exception these plants are all introductions to the United States from other countries.

How do bees learn to open up a flower in this way? Is there a parallel between their behaviour and that of the small birds that peck open, with such irritating persistence, the metal caps of milk bottles in order to drink the cream? I have yet to find a convincing answer to these questions. Nevertheless, one thing is clear: the behaviour is not natural because it is not normal. If it were, the unlucky flowers that were robbed illegitimately of their nectar would surely run a grave risk of extinction.

Chapter Twenty-two

BEES AS PRODUCERS OF HONEY

TO THE majority of people, perhaps, the bee is a symbol of honey. It is not easy to think of one without the other. And yet, of the total number of different kinds of bees known, only a very few indeed produce honey in quantities large enough to be worth gathering.

I confess that I find the making of honey among the less interesting things that bees do. If it were not for the coincidence that both bees and man have a sweet tooth, I am sure we should have very different ideas about bees and their ways.

The familiar honey-bee has been associated with mankind for a very long time; beekeeping in some form or another is almost as old as history itself. Mythology, folklore and legend abound in fables about bees. Is it really to be wondered at that the honey-bee, so far removed from man in the scale of living things, should have acquired a position of honour and esteem in his social economy? Certainly the emphasis on what is important about the honey-bee has shifted somewhat. As a pollinator of flowers it stands higher in our estimation than as a producer of honey. And as for honey itself, it must be admitted that nowadays the sugar of the cane and the beet has a wider and more enthusiastic public.

Although the honey-bee has been exploited for thousands of years, no one really knew anything much about it until comparatively recent times. An aura of mystery and superstition surrounded its activities, and the details of its life history were obscured beneath an amazing tangle of queer notions and misunderstandings. It was not until the seventeenth and eighteenth centuries that a handful of brilliant observers, among them François Huber, began to reveal the truth about its biology. We find it hard to believe now that for nearly three thousand years a myth persisted that the decomposing carcass of an ox or bull could generate, as though out of nothing, a swarm of bees. The most precise instructions were given for preparing the carcass: all the orifices of the animal were to be stuffed with some material, and it was to be left undisturbed for a certain length of time. Why should anyone have doubted that the insects that arose from the rotting and liquefying mass of flesh were bees at all? They looked like bees, therefore they were bees. We need not feel superior if the ancients made a mistake of this sort. We often confuse flies with bees, though we need not blush at the error. After all, knowledge of insects, though there is a vast body of it, is possessed by very few people.

The spontaneously-generated swarms of bees were almost certainly two-winged flies of the order Diptera. The fly whose claims have been most successfully argued belongs to the group or genus called *Eristalis*. These flies are very like bees to look at, and their grubs, popularly known as rat-tailed maggots, normally breed in fetid puddles. Or are we being too kind to these bee enthusiasts of long ago? Could their error have been more gross? Did they mistake swarms of emerging bluebottles—those useful insects whose voracious grubs rapidly reduce a carcass to a bag of bones—for honey-bees? We shall never, I fear, know the truth, but that is of no special importance, for the answers are only of historical interest. The myth, by the way, is called Bugonia.

The Stingless bees of the Tropics have probably had as long a connection with man as the honey-bee. Unfortunately, the various peoples whose territory they have shared have left us fewer records. Dr. Schwarz, who has probed more deeply than anyone the sources of information about these bees, says that their honey, and also their wax, has always been greatly valued by the Indians of Central and South America. There seems to be no limit to the uses the Indians have found for these two products, hardly an ailment that cannot be cured with the aid of honey. For disorders of the ears, nose and throat it was considered especially good, though one cannot help thinking that its chief use was to make the rest of the medicine more palatable. One of the remedies for curing ear-ache was to drop into the ear a little honey that had been heated over hot ashes in an old ripe, red chili.

The honey of the Stingless bees varies much in flavour, and it does not keep so well as the honey to which we are accustomed, turning sour very quickly, even after a few hours in some cases. And it has another peculiarity: it resists granulation and remains fluid indefinitely.

It is not possible to be positive in making statements about the honey of the Stingless bees, for it has not been so thoroughly analysed, nor its properties so carefully studied, as the product of its competitor, *Apis mellifera*. It certainly seems that some of the honeys made by the Stingless bees have excellent keeping qualities, for there is a record of honey having been kept in jars for as long as thirty years without showing signs of crystallization.

The honey of the Stingless bees has been of immense importance to the native peoples of South America. It was the principal source of sweetness to the Indians before the white man crossed the Atlantic and took with him the honey-bee of the Old World. And it was not only its sweetness they liked; they enjoyed it sour and fermented, and gently potent with alcohol. The mead they make is said to be mild in its effect. Opinions, however, differ on this point and depend on what one is used to. It does seem, though, that the Indians, like our own forefathers when they discovered the magic properties of fermented honey, do sometimes prepare heady brews of extreme potency. Earlier travellers from Europe, whom curiosity and the desire to expound the advantages of a gentler way of life enticed to the New World, have sometimes written harsh things about the drinking bouts of the Indians. According to the eighteenth-century Jesuit missionary, Florain Paucke, the Indians of Paraguay would prepare at a certain time of the year a special liquor from the honey of the Stingless bees. They would drink this until they fell into a stupor; and when they awoke they would drink again. The effect of the wine on them when they were not asleep was to make them so violent that their wives, fearful of serious accidents, would always take the precaution to hide away their weapons.

As an everyday article of their diet the Indians serve honey as a sweet drink, diluting it first of all with water. It is served in the same way by the Aborigines of Australia. In Brazil it is customary to boil the honey as soon as it is taken from the bees, so as to make it thicker. The boiling doubtless improves its keeping qualities by driving off a good deal of water and thus increasing the concentration of sugar. If the sugar concentration is high enough, plant ferments, such as yeasts, cannot live in the honey.

Perhaps it would be a quibble to say that it is only partly true that bees make honey. They are certainly not responsible for its entire manufacture. All they do is to render the crude material into a chemically different substance by changing the proportions of its sugars. The crude material is the nectar that the bees gather from the nectaries of various plants. Its transformation into honey is all a matter of sugar chemistry. The sweetness of nectar is due to the presence of sucrose, which is only one of many kinds of sugars recognized by the chemist. Once inside the bee's crop the nectar has entered a factory to be processed into another sweet substance, honey, in which form it evidently suits the purposes of the bees better. Certain chemical ferments, called enzymes, act upon the nectar so that its sucrose is broken down or inverted into two simpler sugars, levulose or fructose, and dextrose.

One of the most interesting features about the honey of *Apis mellifera* is its variability. It may be almost as clear and colourless as water or as dark as the old-fashioned treacle that one used to buy straight out of a barrel. And yet it remains pure honey, its colour, flavour and aroma depending on the kind of flowers from which, as nectar, it was gathered by the bees.

It would be quite wrong to assume that the sweet viscous substance stored by the bees in their combs is always derived from the nectar of plants. Nothing that is sufficiently sweet comes amiss to them, and they will happily lick up the sticky varnish, or honey-dew, that often covers the leaves of trees such as oaks, limes and sycamores. Honey-dew is looked upon as a substance of somewhat mysterious origin. Pliny thought it fell from the stars, but today no one believes it to have come any farther than from the tissues of the plant itself. It may be because the facts of its origin are somewhat distasteful that many people persist in accepting honey-dew as a sweat-like exudation secreted by the leaves. Actually it is a waste product excreted by certain kinds of insects. In Great Britain the chief culprits are the Aphids, or greenfly. Sometimes nothing seems to hold up the boundless procreation of these prolific little creatures, and they begin to populate the trees in countless myriads. Through their beaks, that pierce the tenderest parts of the plant, there passes into their bodies a constant stream of sap. The Aphids suck up far more than they actually require to keep themselves alive. What they cannot use passes through the anal opening and falls as honey-dew on to the foliage below. In summers with a normal rainfall the honey-dew is washed away and is no temptation to the bees. But in dry seasons it may remain for weeks on the leaves, offering an alternative food supply to the bees at a time when plants through the drought are not producing their nectar freely.

Honey-dew in its pure form is colourless and sufficiently sweet for the bees to want to gather it. But it soon becomes the breeding-ground of various kinds of moulds. These, at the conclusion of their own complicated development, leave it darkened with spores. The spores are taken up by the bees and find their way into the honeycomb, where they give this false honey its characteristic dark unpalatable appearance.

All this concerns the storing habits of the common honey-bee. Much less is known about the origins of the honeys made by the Stingless bees. It seems that they exist in endless variety, for they are the product of very many different kinds of bees. As for the taste of these honeys, some are almost uneatable, but a few have a very pleasant flavour. But this does not bother the natives of the tropics overmuch for they are less fussy about the quality of honey and its standard of purity than we are.

The South American Indians keep colonies of Stingless bees in hollowed-out logs. To remove the honey they only need open one end of the log hive and carefully take out the large waxen jars in which the industrious little bees have laid up their stores. When I described the habits of the Stingless bees, I mentioned that they do not build combs in the same way as the honey-bee. They cannot, therefore, be kept in hives with movable frames. A hollowed-out log or an earthen jar makes as good a home as any.

There is one other class of bee that occasionally produces enough honey to make the plundering of its nests worth while. These are the bumble-bees. Like the honey-bee they keep up a fairly high temperature in their nest, deriving the energy to do this from the honey they store. They help to conserve the heat by tightly packing the nest around with whatever material is at hand, such as dry grass or dry leaves. Some species are content to live a more or less hand-to-mouth existence, laying in but little more honey than they need for immediate requirements. Others are more provident and like to maintain a surplus. Sladen said that a populous colony might fill as many as 400 vacated cells, or rather cocoons, with thick honey. I do not remember that he said anything about the flavour.

As far as I know the bumble-bees have never been exploited by man for their honey. For one thing, it is not particularly easy to find their nests, and for another no one likes to risk getting stung for the sake of a couple of spoonfuls of honey. Skunks in North America and badgers in Europe apparently have other ideas about the matter. They like to dig out the nests of the bumble-bees and regale themselves not only with the honey, but with the juicy grubs also.

Thus we find that against the total number of bees so far discovered, honey can be taken only from the social species; and among these it is only the honey-bees and the Stingless bees that produce it in useful quantities.

Chapter Twenty-three

HOW TO STUDY BEES

For some of us it is not enough to read about insects in a book, however interesting they may be. We would like to get to know them a little more closely and, studying them at first hand, find our own pleasure in them.

Now if it is bees that excite our curiosity they have one rather special advantage over most other insects. They are about when the weather is at its best, just those times of the year, in fact, when we feel most strongly tempted to escape into the countryside away from the tedium of everyday existence.

Are we to go forth armed with a net and a killing-bottle in search of our quarry, or can we be content, like the hunters who do their hunting with a camera, to study them alive? It is possible to do both and get plenty of enjoyment either way. Of course we know that the true field naturalist likes to warn us against the sordid delights of making collections of insects, pointing out that a row of pinned and shrivelled bodies in a box or cabinet drawer at best satisfies a collecting mania that should be suppressed instead of encouraged. In his enthusiasm for the living forms of nature he is apt to forget that every plant or animal that fills him with wide-eyed wonder has at some time been minutely studied as a dead specimen and given the name by which he knows it and communicates his ideas about it.

We need not, therefore, pay much attention to anyone who would like to oppose a harmless inclination to make a collection of bees on the grounds that it is cruel to kill them, or that by catching them we deprive others of the pleasure of seeing their beauty. As a matter of fact, it is almost impossible to get any aesthetic delight from the sight of bees unless you have them at close quarters. Some of the bumble-bees are big and brightly coloured, and pleasant to see as they fly around. But bees generally, at any rate those of Great Britain, are no competitors of those showy insects the butterflies. The Red Admirals that cluster on the ripe fallen pears in autumn are lovely to look at. But who gives more than a passing glance at the honey-bees that are greedily feeding on the juice at the same time?

Let us be honest and admit that if the small bees that bustle about among the flowers were not there, most of us would be none the wiser. I am saying all this to remove any scruples you may still have about catching and killing bees. If you can bear to take the plunge, you will be collecting something really worth while. To sit down with a strong hand lens, a box of unnamed bees and a book from which you can find out their names is a pleasant and satisfying way of spending a winter's evening. Moreover, you will be initiated into the austere delights of what is so unromantically called systematic entomology. You will discover what is meant by the family, the sub-family, the genus and, if you are painstaking, the species in so far as it is defined for the purpose of practical classification. The word 'species' is nowadays so heavily charged with ideas that you cannot touch it without getting some sort of a shock. All this, however, has to do with the species as a living entity in nature and not as a dead specimen in a box.

Bees are among the most pleasant of all insects to collect. No more effort is needed than to station oneself where wild flowers abound and catch the bees with a net as they visit them. Sharp eyes are a great help, of course, for many of our native species are very small and could easily be mistaken for other insects. Nevertheless, with a little practice it soon becomes easy enough to recognize them. The females in particular go about their work of collecting nectar and pollen with a business-like air that quickly betrays them. And some, such as the bumble-bees, and the *Anthophoras* that hover like miniature helicopters, can be recognized by their stocky build.

It is outside the scope of this book to give detailed instructions on how to collect and preserve bees. The fullest information on the subject can be found in a little work called *The Hymenopterist's Handbook*, brought out by the Amateur Entomologists' Society.

The man to whom the idea of killing bees is abhorrent can study them in the field. He need have no fear that all has been discovered about their habits. The broad outlines of behaviour are, for the most part, well known, but very little is known about the detailed behaviour of individual species. Sometimes there are quite large gaps in our knowledge of their life history. They can be filled in only by studying bees as living organisms in their natural surroundings.

Some bees pass the winter in the grub stage, others as adults. Have these adults been flying in the summer of the previous year, or are they appearing in the spring for the first time? This, you might think, should surely be known. It is—for some species. But there are many others about whose habits we are ignorant or hold conflicting opinions.

A long time ago a violent argument about how many teeth a horse has was stopped by someone suggesting that it might be a good thing to look inside a horse's mouth and count them. This may be a legend, but it reminds me that recently I came upon a striking difference of opinion concerning the wintering habits of those little bees called

Halictus that have so often been referred to in previous chapters. On the one side it was maintained that the general habit of these bees, at least in Northern Europe, was to pass the winter as larvae, turn to pupae in the spring, and emerge as fully-fledged adults shortly afterwards. The opposing view, which I believe, on circumstantial evidence, to be the correct one, is that these bees overwinter as adults that left their cells and mated the previous late summer or autumn. The field worker has the chance of proving which of these two views is correct. He has only to find colonies of *Halictus*, make sure of the identity of the species he is watching, and see how it behaves in the autumn. If it is going to pass the winter as a larva then the females will be seen carrying pollen to their burrows and engaging in all the activities that belong to raising a family. If no pollen comes in, then the bees have some other intention. And, in any case, we may remember the legend of the horse's teeth and decide to settle the matter of how *Halictus* spends the winter by digging down into their nests at just this time of the year and seeing what they are doing.

There are other interesting problems in the life of *Halictus*, too. How, for instance, does it generally behave in the presence of its persistent persecutor, the little black-and-red cuckoo-bee, *Sphecodes*? The parasitic habits of these bees, you may remember, were not suspected for a long time. Gradually, when it was seen that the females never carried pollen and indeed had no organs for carrying it, and that they were always searching among the burrows of *Halictus*, it became evident that their interest in other bees' nests was more than a passing one.

There are many different kinds of *Sphecodes*. We cannot assume that they all behave in the same way as the species *monilicornis*, whose curious habits I have already described. Only patient observation will reveal the general pattern of their behaviour when the time comes for them to meet the resistance of their hosts.

For those to whom the social life of bees make a special appeal there is the bumble-bee's nest and the observation hive of the honey-bee. *The Hymenopterist's Handbook* gives careful instructions on how to dig out the nests of the former and set them up in boxes where the routine of social activities can be comfortably watched.

There are several species of bumble-bees in Great Britain about whose nesting habits we know little or nothing. This is perhaps understandable, for they are rare or found only in a few favoured localities, and their nests are hard to find. But the last word has not been said about the habits of the commoner species, and anyone who cares to keep their nests in captivity has the chance of making fresh discoveries. Let me tell you about one curious piece of behaviour that needs to be explained.

One of our commonest bumble-bees is *Bombus lapidarius.* It is a handsome insect, entirely black except for a deep red tail, and it has a preference for nesting in open country such as downland and hedge banks. If its nest is kept so that the queen and workers can be watched at their tasks, the queen will sometimes be seen preparing a little cell and laying a batch of eggs in it. Why is it that after she has finished, the workers nearby make vigorous attempts to tear open the cell and eat the eggs? The queen shows every sign of being disturbed by the threat to her eggs and for a time guards her cell until the workers decide to leave it alone.

Sometimes a bumble-bee's nest will contain one of the cuckoo queens, and then there is always the chance of finding out some new and interesting fact about her behaviour. It would be useful to know more about the attitude of the queen mother towards this destructive intruder and how she is finally reduced to impotence by the more powerful cuckoo.

As for the honey-bee, so much is now known about its ways because of its close association with our own economy that new facts about its biology are not likely to be obtained by casual observation. But all the thrill of actually observing the manifold and complex activities of the workers can be got from the proper use of a special observation hive. This is essentially a narrow glass-sided case, wide enough to take a single comb in its wooden frame and deep enough to hold two or three such combs. The bees, as they move over their combs, are close up against the glass and can be observed with a hand lens. An entrance tunnel is fitted to the hive so that the bees are able to fly out and obtain the materials they need for self-support. When nectar is coming in freely there is always the possibility of seeing the famous dances. They are not in themselves spectacular, but the startling interpretation that von Frisch has given them makes them worthy of special attention.

And then, when we take to studying the habits of bees, there are all those intriguing questions about instinct and the effects of environment and whether a bee is intelligent or not. To what extent, for example, are they slaves to their environment? And how far can that part of their behaviour which we call, for want of a better term, instinctive, be modified?

Naturally, in order to appreciate how far a bee can behave in a way that is not normal to it, you must have a pretty clear idea of how it behaves in ordinary circumstances. If you saw a bee carrying a piece of leaf into a hole in a fence you would not regard your observation as anything unusual. You would have recognized one of the leaf-cutters and known that it normally lines its cells with pieces of leaf. But sometimes the unexpected happens and you see a fragment of behaviour that does not fit into the normal pattern. An instance of the unusual has recently been recorded by a Belgian hymenopterist—Crevecoeur.

Crevecoeur records that a female of one of these leaf-cutter bees, *Megachile centuncularis* by name, a species that make use of many different plants, had broken all the rules in the choice of her nest material. She was cutting her wallpaper from the red petals of a geranium (Pelargonium). Whatever determines that a bee shall make her nest in exactly the same way as her mother failed to guide this female in the choice of her material. Why she went to the red petals instead of the green leaves is a question I cannot answer. But observations of this kind are the stuff out of which new theories concerning the habits of insects are built up.

The brilliant observations of Henri Fabre and Charles Ferton show how much can be revealed if once insects work their spells on you so that you fall in love with them and are driven to probe their secrets. Such men are of exceptional calibre and most of us cannot hope to emulate them. But even if we lack the perseverance and patient skill that brings fresh discoveries, we can still get a lot of fun studying bees in our own private way. Their habits are rich and varied enough in themselves to provide constant entertainment for a lively curiosity. And if these insects, whose ways, I hope, are no longer a mystery to you, do no more than take us into the sunshine, then we can be grateful to them. For in their company we shall most certainly forget our cares and find pleasant recreation.

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